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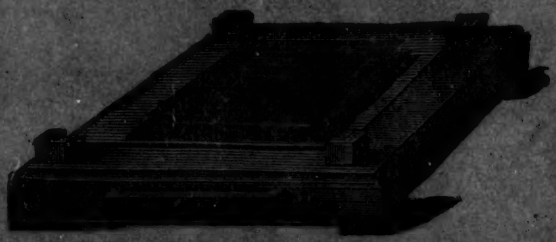

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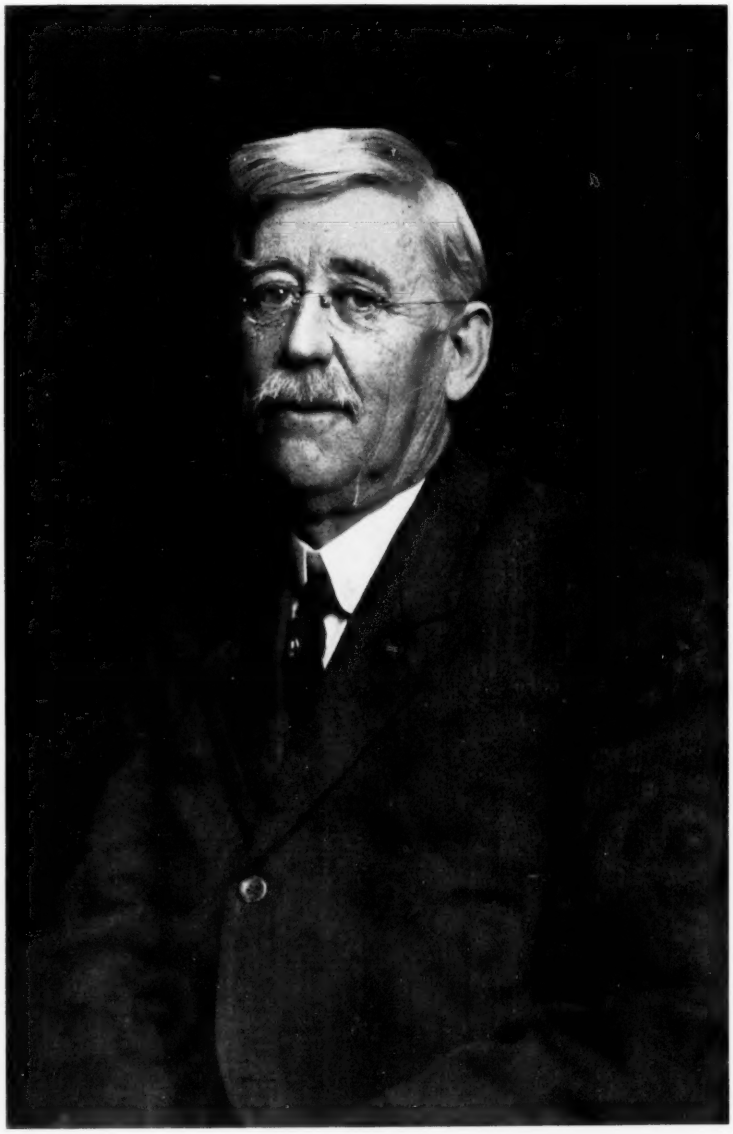

BYRON DAVID HALSTED

PHYTOPATHOLOGY

VOLUME IX NUMBER 1

JANUARY, 1919

BYRON DAVID HALSTED, BOTANIST[1]
(1852–1918)

DAVID FAIRCHILD

WITH PORTRAIT. PLATE I

It is a curious fact that, although we have certain formulas according to which we describe plants—even microscopic ones—we have no set rules to guide us in the description of ourselves as human beings, and it is surprising what scanty room we devote even in our scientific publications to the descriptions of those human beings to whom the literature of science owes its existence. Perhaps it is the difficulty of the task which prevents us. Possibly it is because those upon whom the task falls have learned to describe plants but have never been taught to describe members of their own species. The fact remains that the shadows of these great men pass, and the coming generations who pore over their work form vague notions about the forms which made these shadows, the sound of their voices, the effect of their presence, or the light of their eyes. All this seems strangely true, as I attempt to write these lines about my uncle, Dr. Byron David Halsted, whose life has just closed at the age of sixty-six.

[1] Byron David Halsted, son of David and Mary Halsted; born June 7, 1852, at Venice, N. Y.; died August 28, 1918. He received from the Michigan Agricultural College the degrees of B.S. in 1871, and M.S. in 1874, and from Harvard University the degree of D.Sc. in 1878. He was editor of the American Agriculturist from 1879 to 1885; from 1885 to 1889, Professor of Botany in the Iowa Agricultural College; and from 1889 to 1918, Professor of Botany and Horticulture at Rutgers College, New Brunswick, N. J. Silver Medal Massachusetts Horticultural Society; Fellow, A. A. A. S.; Member; Society for Plant Morphology and Physiology; Society for the Promotion of Agricultural Science, of which he was president in 1897; and the Botanical Society of America, of which he was president in 1900. Associate Editor, Bulletin Torrey Botanical Club, 1890–1893. Member Advisory Board, North American Flora since 1905. A pioneer in American Botany and Plant Pathology, Dr. Halsted contributed some 300 titles to the literature of these subjects. His work on plant diseases in New Jersey was particularly important. After 1900, he specialized on Plant Breeding.

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It occurs to me that what the younger generation of botanists would like to have recorded are some of those glimpses into Dr. Halsted's character, which were given to me not only as his nephew but as his botanical protegé—such impressions, scattered through the years, as come to mind whenever his name is read or spoken.

I first see him with the eyes of a child of seven, at Lansing, Michigan. He had ordered a pocket microscope, and we children knew he was waiting impatiently for it to come, so we filled a box with angleworms and addressed it to him and put it in the mail box and waited for him to come home and saw with malicious delight his disappointment as he opened the box. Of course he chased us—nothing short of that would have satisfied our idea of adventure.

I next see him through the eyes of a youth of eighteen in a thicket along the banks of Wildcat Creek in Kansas, wandering in his characteristically inquisitive way, glancing at leaves, turning over old logs, or examining buds. A passion for strolling in the woods, as I remember him then, was one of his characteristics. To him the woods presented a charm which might be described as coming from the fascination of apparently little things. It was very distinct from the collector's spirit. Because he knew he could name a plant did not make him hurry by it to the next. He examined it and stopped to wonder whether in it did not lie some problem either connected with its apparatus for seed distribution, or a contrivance for cross-fertilization, or whether on its leaves was not to be found some leaf-spot disease, or whether the hairs of its pubescence were not peculiar. He appeared to take an unending delight in the vast array of beautiful forms and colors which are everywhere to be found in the minute structure of living things. There was something of the fascination in it that a child shows when he first holds a kaleidoscope in his hands and turns it before his eyes; but with this difference—each new form suggested some interesting problem to be tried. He never tired of looking, and there always seemed to me to be something of the quality of Franklin's mind in that of my uncle. If a leaf fell too early, his mind enquired at once why it fell, and he looked for a disease or some other cause. His mind did not dismiss the matter as of no particular consequence.

The summer and autumn of 1888, which I spent with my uncle at Ames, Iowa, in the old brick North Hall, were days of delightful enthusiasms, during which I learned from him that investigation should be a series of exciting experiences. His great power as a teacher, as I saw it then and can now compare it with that of Brefeld, Cohn, Pax and other German botanists, lay in his refusal to consider any field of research as old. He delighted in dipping into any problem regardless of the volumes which might have been written on the subject, and instead of making his

pupils feel that so much had been done that it was very hard to find a place where they might expect to discover something new, he encouraged them to believe that they might start in almost anywhere. He gave them first the pleasure of their own discovery, even if later they found out that somebody before them had found out the same fact. To a youth, the idea of research as an exciting sport was the important thing to establish. He refrained from taking the student into a great library of obscurely presented facts and theories and overwhelming him with the magnitude of the knowledge already assembled. I never discussed this matter with him, but I always believed that he felt there could not be too many independent unbiased witnesses of a natural phenomenon and that it was not a crime to fail to find out by a long literature search if some one else before him had described the same thing.

In 1888 the world of fungi imperfecti presented a new and fascinating field, and every leaf spot was put under a tumbler to bring out its streams of pycnospores, if it had any, or scraped with a scalpel to discover its bundles of aerial hyphae. The powdery mildews and rust fungi were not well known then, and many were the attempts made to germinate them—many failures it must be confessed.

Pollen always seemed to have a peculiar fascination for my uncle, and he gathered it fresh from every flower almost which came to hand, and germinated it in sugar solutions. This was before the days of microtomes and just about the time when Douglas Campbell and W. H Wilson had returned from Germany with ideas on how to stain the nucleus with methyl green or eosine.

Of Dr. Halstead's student days in Harvard I often heard many stories. He was proud of having been Dr. Farlow's first pupil in plant diseases and of the pioneer work on Plowrightia morbosa which Dr. Farlow did he was, I believe, an enthusiastic witness.

There was a period of my uncle's life of which I know only through hearsay. It was of the years when he was associated with Thurber on the American Agriculturist. Those were his days of journalism and of busy city experiences, when he read proof and investigated fraud advertizers for the paper. For. Dr. Thurber's mind he always had great respect and often quoted his quaint, humorous and sarcastic sayings. In so far as environment affected him, these days tended to make him an easy, fluent writer. He had a simple style, using short Anglo-Saxon words, and his delicate sense of humor often came out in his writings.

In microscopic research, his methods were the direct ones of hand manipulation, for he had a very quick eye to determine correctly occurrences in the microscopic field. He would much rather actually see a spore sitting on its conidiophore and by pressure on the cover-glass jar it loose

than by reasoning because there were hosts of spores floating about in the field and sporeless conidiophores present, that the spores came from the conidiophores and did not come as the result of contaminations. He wanted to actually see with his own eyes, and he was in the habit of checking his methods by means of actual observations, much as Brefeld did when he proved the nature of the spores of Bacterium by watching one actually germinate.

Dr. Halsted's philosophy of life was essentially the Christian one. Born of Quaker ancestry, he maintained through life the quiet simplicity of the Quakers, although in his religious beliefs he adapted himself to the Congregational and Presbyterian faiths.

During the long years of delicate health, at the close of his life, he wrote for his intimate friends some charming short poems and essays.

His was not an aggressive personality. He did not delight in argument, although he seldom failed to contribute his opinion whenever he thought it was wanted or would help clarify a situation. He won people through the nobleness of all his motives, for nobody could find in them that selfishness which so many people believe is necessary to self preservation.

Physically, my uncle was not particularly robust when I knew him, although as a student he was pitcher of the college baseball team and because he was ambidextrous, he often confused the batters. Though a great walker, his feet troubled him as he grew older and limited him to the small amount of foot travel which the observations in his plant breeding plots necessitated. He was not a great traveller, though he knew the New England States and had crossed the continent, but he never visited Europe. When he arrived at the age when he might have travelled much, railroad travel had become distasteful and even painful to him, and besides, he found so much to interest him in his laboratory and greenhouse that he did not care to go away.

There always seemed to me to be a characteristic disorder about my uncle's laboratory. It was different from the general run of experiment station laboratories with their neat array of apparatus and specimens. There were so many interesting problems going on, so much improvised, make-shift apparatus. If you found a rotten carrot which you thought was there merely because it had not been thrown away, it was probably being kept to see if the disease causing the rot would develop perithecia. He had the true idea regarding research. He did not postpone an investigation until Bausch & Lomb could provide the apparatus, but he went at it with his pen-knife and a ball of twine. There is an American saying which appears to fit Dr. Halsted's character in this respect: "Anyone can build a house with a full set of tools, but to make a piano with a jackknife—that's art." He delighted to secure results with simple means.

Whether he realized more keenly the flight of time than others, or whether his journalistic training had given him the habit, I do not know, but he followed the practice of putting into print his observations as they were made, without waiting to give to them the polishing which some investigators deem essential. I cannot help thinking that this habit was in his case a fortunate one, for had he waited as so many of us have done until out investigations are properly rounded out, he would have left to the world much less that is really valuable. He carried on investigations extending over many years, but as he went he published his observations. By those who delight in monographs or in single great pieces of work, Dr. Halsted will be criticized for covering so wide a field of botany and for not specializing more narrowly, but this was not his nature, and when I try to compare him with men who have spent fifty years monographing a single family, I cannot do it. They are not comparable, and nothing is to be gained by trying to make them so. A single correct observation may be quite as valuable as a life-long elaborated theory. Brefeld's observation of the sprouting bacterial spores, though made in twenty-four hours, will be remembered and already outclasses his *System der Pilze* on which he spent years of his life and in which he believed with an almost religious fervor.

It is a pity that eyes so keen as Dr. Halsted's should not have been correlated with a greater endurance, for the hard usage which he subjected them to broke them down too soon and forced him, long before he was past middle life, to abandon the microscope altogether. It was when this time came that he shifted his investigations from the field of plant pathology to that of plant breeding, in which latter field he accomplished a great deal that is of lasting value; and, considering his delicate health, it is remarkable what he was able to accomplish, thanks to the appreciative attitude of his colleagues of the New Jersey Experiment Station and the faculty of Rutgers College.

It perhaps ought to be recorded that his removal from Iowa to New Jersey, which will appear to most people as significant, came about through the fact that his wife's relatives were New Jersey people; and in the eighties, Iowa was a long way west, and life there lacked many of the attractions of the East.

Of my uncle's ancestry I know too little. That there were inherited traits urging him towards the scientific career which was his, there are, however, evidences; for one of his granduncles was Dr. Joseph Thomas (compiler for Lippincott of the American Encyclopedia of Noted Men), who was sent by Wm. H. Seward, then Secretary of State to make a report upon the resources of Alaska, upon which favorable report Seward acted. Another great uncle was David Thomas, Civil Engineer of the

Erie Canal under DeWitt Clinton, then Governor of New York. John J. Thomas, of Union Springs, N. Y., a noted horticulturist of his time, author of Culture and Management of Forest Trees, Fruits, Nuts and Vines, was Dr. Halsted's own uncle and possibly influenced him as a small boy in the choice of his career. I do not mean to underestimate in the least, however, the environmental effect of the early pioneer days in the Michigan State Agricultural College when .President Abbott, Dr. Kedzie, Dr. W. J. Beal, Dr. A. J. Cook, Dr. Miles, and my own father, Pres. Geo. T. Fairchild, were working out the scheme of agricultural education which has had such an effect upon our country.

Dr. Halsted was a contemporary of Bailey, Shelton, Georgesson, Tracy and many others to whom not only this country but Japan owes a debt of gratitude for their pioneering efforts. Professor Tomari, the first Japanese agricultural student to America, studied in Michigan during those days.

With Dr. Halsted's death, there has passed not only a great soul, whose ideals live in his pupils, but a personality in research which was characteristic of an epoch in botanical science—the early days of plant pathology.

To those who in their researches run across one of his new species of fungi or early descriptions of a plant disease, I would point out, that behind the descriptions which they read, lies the soul and intellect of an American who believed that the evolutionary drift of mankind is toward a greater altruism.

We are, all of us who do scientific work, gathering grains of sand "on the seashore of endless worlds" and it is a satisfaction as his nephew to feel that the grains of sand which my uncle gathered were real grains and not the irridescent bubbles made by the surf.

Dr. Halsted was married three times and three children and his widow survive him: Edwin Howe Halsted, a practical horticulturist in northern New Jersey; Mrs. Rudolph Riege, of Springfield, Mass., and Ella, an unmarried daughter.

THE RELATION OF TEMPERATURE AND HUMIDITY TO INFECTION BY CERTAIN FUNGI[1]

J. I. LAURITZEN

INTRODUCTION

Very early in the history of plant pathology a fundamental relation between weather and plant diseases was recognized, not only by the pathologist but by the farmer. Even before anything was known about the nature of diseases, the weather was thought to have an intimate connection with their causes, and by many to be responsible for their production; and yet very little work has been done to analyze the exact manner in which weather conditions affect diseases or disease production, except in an observational way.

The effects of temperature, humidity, rainfall, and dew have not been isolated, except in a few cases, and then chiefly from observation or under partially controlled conditions. Never, so far as the author is aware, has the influence of temperature and humidity upon infection been studied separately where both have been under control.

The importance of taking cognizance of the one while studying the other in connection with any growth phenomenon will be emphasized from the following examples of the influence of temperature and humidity on the growth of bamboo. Shibata (28), working under field conditions in Japan, gives a table which indicates a close relation between the daily growth of bamboo and temperature (16°C. to 20°C.) and scarcely any relation to humidity. Lock (19), working at Peradeniya, on the other hand, found that the daily growth depends largely upon the water supply and the moisture content of the air, and has little relation to the temperature, which in his experiments fluctuated beween 19° and 26°C.

The difference in the temperature of the two places will account for the seeming discrepancy, as far as the temperature is concerned. At Peradeniya the temperature is apparently the optimum for the growth of bam-

[1] Also presented to the Faculty of the Graduate School of Cornell University, March, 1916, as major thesis in partial fulfillment of the requirements for the degree of doctor of philosophy. The writer is indebted to Dr. Donald Reddick and Dr. V. B. Stewart under whose immediate direction the work was performed for valuable assistance and suggestions in connection with the investigation and in the preparation of the manuscript.

boo, and covers a range of several degrees, while in Japan it falls below the optimum, consequently the growth curve follows closely that of the temperature. A comparison of the humidity of the two regions, as far as a comparison is possible from the data that are available, reveals very little difference in the moisture content of the air. It is apparent that this humidity, which varies largely between 70 per cent and 90 per cent influences the amount of growth under the favorable temperature at Peradeniya. Its influence is evidently obscured by the unfavorable temperature in Japan. Whether the humidity can become so unfavorable as to obscure the effects of temperature is not known from the data at hand, but it is probable. One thing seems certain, however, that in studying either of these factors one cannot afford to ignore the one while the other is under observation; in fact, it would be preferable to hold one of these factors constant when observing the other.

In earlier work in pathology a clear distinction has not been drawn between the infection period and the period of incubation.[2] Such a differentiation is not always possible, and perhaps it is never possible to state definitely the exact point at which the infection period ends or the period of incubation begins. However, in most cases they can be separated sufficiently to study each apart from the other. Considerable work has been done to show the influence of temperature on the production and development of disease, but the two periods have been studied conjointly. Less work has been done upon the relation of humidity to this phenomenon but a sharper separation has been made between the infection and incubation periods.

Balls (4) conducted temperature-infection experiments with Rhizoctonia (*Corticium vagum* B. and C., var. *Solani* Burt) on cotton (*Gossypium spp.*) in which he found that infection took place and became evident in twenty-four hours at a temperature of 20°C. At 33°C. no infection occurred. Here the infection and incubation periods are crowded into such a short space of time and apparently so fused together that probably it would be difficult to separate them. The experiments were conducted by placing mycelium of the fungus in contact with seedlings placed upon several layers of moist filter paper in a petri dish, which in turn was placed in an infection chamber.

Gilman (11) performed some soil infection experiments with *Fusarium conglutinans* Wollenw. on cabbage (*Brassica oleracea* L.) which are of interest in this connection chiefly because he worked in a greenhouse in which the temperature was automatically controlled. He also conducted some

[2] Infection period as here used is the period during which the pathogen penetrates the host until it becomes established with the host. Incubation period is the period of development that follows until the symptoms of the disease become visible.

experiments in a glass infection chamber where the temperature was controlled by an electric thermo-regulator. The difficulty of studying infection apart from the incubation period is here apparent. It is not, however, so important in this instance that they should be studied separately, because the environmental factors are not so variable except in the case of temperature.

Tisdale (29) studied the infection of flax by *Fusarium Lini* Bolley. He found that the lower temperature limit for infection was about 15°C., and makes the statement that most of the infection occurs between 20° and 30°C. The temperature was controlled in one set of experiments by employing positions at different distances from a radiator in a green house, in another by means of a circulating water jacket about the plant containers. He also investigated the influence of temperature upon the growth of the fungus in culture media, and determined the limits to be 10° and 37°C. with an optimum temperature at 26° to 28°C.

Johnson (14), in working with *Thielavia basicola* Zopf. to test the range of parasitism on a large number of plants, controlled the moisture content of the soil and recorded the soil and air temperatures. The temperature of the air and soil depended upon greenhouse conditions.

Fromme (10) was unable to produce infection on oats (*Avena sativa* L.) by *Puccinia coronifera* Kleb. with a relative humidity of 75 per cent to 80 per cent and a temperature of 55° to 85° F. He conducted an experiment designed to determine what conditions of humidity were necessary for infection. He grew his plants in an open case made of window sashes where the humidity averaged 93 per cent with a variation of about 2 per cent to 3 per cent. Although he inoculated thoroughly, he obtained only slight infection. In an experiment where one pot was covered and another stood in an open box there was an average of 161.6 lesions per plant in the first case as compared with 10.4 or 6 per cent in the latter.

Some interesting results were obtained by Levin (17) in connection with an experiment planned to determine the time required for the infection of tomatoes (*Lcyoporsicum esculentum* Mill.) by *Septoria lycopersici* Speg. He sprayed ten plants with a water suspension of spores, placing 9 of them in a Wardian case, where a high humidity was maintained by means of a fine spray of water. A plant was taken out at intervals of 6, 12, 24, 36, 48, 60, and 72 hours and dried immediately by an electric fan and placed in an open window until infection became evident. After a lapse of five days all the plants, including the one left on the outside, showed characteristic lesions of the disease. This experiment was repeated in detail, except that the plants after inoculation were exposed to a current of air from an electric fan until the disease appeared. The results were similar to those secured in the previous experiment. Infection was also obtained by applying dry spores.

From the results of these experiments the author concludes that it is questionable whether a film of water over the plant surface for at least a number of hours is essential to infection.

The purpose of the present study is to determine the influence of temperature and humidity upon infection, and to find out whether a film of water covering the surface of the plant is essential for the fungus to become established upon the host.

APPARATUS

The apparatus consists of two double chambers with thermo-electric connections to furnish heat, and power to run fans. The outer chambers are 40 by 54 by 48 inches in size and are made of glass. The inner are 11 inches smaller in each dimension and so placed that there is an air space of 5 inches on all sides. They are constructed of wood except the lids, which are of glass and slope at an angle of 40° from the horizontal. The wood portion is coated on the inside with paraffin of a high melting point to prevent the absorption of water. Both inner and outer chambers are provided with heating coils and thermostats. In the latter case a relay was employed to prevent sticking of the thermostat, which was occasioned by the use of larger wire necessitated to produce the required heat for the outer chamber.

The evaporation surface for the control of the humidity was supplied by open pans containing either pure water or saturated salt solutions. The humidity was read directly from psychrometers upon which was directed a constant current of air from a fan.

FACTORS

In approaching any physiological problem one is confronted with certain difficulties. One of these is the isolation of the particular factor to be studied. The conditions affecting physiological processes are not only numerous, but complex, and sometimes so interrelated as to make their separation impossible.

The usual procedure is to hold all the other factors constant in order to get at the facts of the particular one to be observed. Having thus reduced the problems to simple terms, one might think he could proceed directly to the solution of his problem, but he soon finds that the procedure is not so simple. One should not only have the conditions constant, but they should be at their optimum, and such an accomplishment is by no means easy, if indeed possible, with our present knowledge of the nature of physiological processes, the factors affecting them, or methods of investigation.

In the present study an attempt has been made to keep the known and possible factors affecting infection constant as far as possible with the

means accessible. An attempt has been made to control, in part, conditions influencing the growth of the host plant, such as the fertility, physical properties, organic matter and water content of the soil, light, temperature, and humidity. The first four of these conditions are fairly easy to control; the latter three involve more difficulties. Temperature and humidity have been controlled as far as is possible under greenhouse conditions. Light is the most variable factor and no attempt has been made to control it. The greatest difference in light is between summer and winter. Whether this difference is sufficient to alter the susceptibility of the host plant to the attack of the fungus, or in any way influences the infecting ability of the fungus, is not known. No such influence has been noticed in the present experiments. It would seem that influences of light become less important when making comparison between the successive periods required for the growth of the plants while they attain sufficient size for inoculation purposes.

Temperature and humidity may affect each plant differently, which of course is true of the other factors. The exact range of temperature and humidity favorable for the growth of the plants employed in these experiments has not been determined. A variation in the range with the plant is, however, generally recognized. It would have been desirable to have grown these plants under optimum conditions, but these conditions were not available, besides the optimum for each of these plants is not known. These same conditions also come into operation during the incubation period.

Light as it exists under greenhouse conditions is not known to be a factor. Since light under natural conditions is not usually regarded as the limiting factor in photosynthesis, upon which host and parasite alike largely depend for their organic nutrition, it would seem that the reduction in food due to the reduction in light under greenhouse conditions would not be sufficient to alter the number of infections more than slightly, if at all.

It would seem reasonable to assume that temperature and humidity during the incubation period do not influence the total number of infections if sufficient time is allowed for the viable spores to establish a relation with the host. It is possible that the border-line temperatures and humidities might cause a variation in the susceptibility of the host to the parasite. There is some evidence to support this position in the case of temperature.

Ravn (25), in studying the influence of temperature upon the infection of barley by Helminthosporium, found that the incubation period was forty-eight hours in a warm greenhouse as compared with seventy-two hours in a cold house. The total amount of infection was slightly in favor

of the cold house. Fifteen out of 16 plants were infected in the cold house, while 12 out of 15 in the warm house were infected. He concludes from this experiment that temperature does not alter the total amount of infection.

Fromme (10) obtained similar results with *Puccinia coronifera* on oats. Plants inoculated and grown at a temperature ranging from 20° to 30°C. showed evidence of infection on the fourth day, while plants inoculated at the same time and grown in a greenhouse at a temperature varying between 14.5° and 21°C. showed indications of the disease only after seven days. This experiment was repeated with similar results. There was a slight difference in time due to a difference in temperature, but the variation was in the same direction. The degree of infection was not, however, different in the two cases.

It seems in the foregoing cases that the temperature employed, whether high or low, was sufficiently favorable to permit of the maximum amount of spore germination, or at least these temperatures allowed about the same percentage of germination; otherwise there would be a difference in the number of infections, unless we assume an alteration in the capacity of the fungi to cause infection or of the hosts to resist it. The latter seems less feasible because it would be a remarkable coincidence if there should be a shift of virulence or susceptibility in such an exact ratio that we would have the same number of infections even though there were a shift in the percentage of germination, especially when we are dealing with two different host plants as well as two pathogens.

Mains (20) by altering the humidity during the incubation period obtained more infection on corn by *Puccinia sorghi* Schw. under high humidity than under low. He employed only 12 hours as an infection period and it is possible that there would have been more infection where the plants were under low humidity had the infection period been extended.

CONDITIONS AFFECTING THE INFECTION PERIOD

The light in the infection chamber was much reduced. First, because the inner chamber was partially constructed of wood; second, the light that reached the plants passed through two panes of glass; and third, the source of light was the diffused light of the headhouse. (It would have been desirable for the inner chamber to have been of glass, but such a chamber was not available.) Whether this subdued light for a period of twelve hours was sufficient to alter the relation of host and parasite can not be stated from our present knowledge. It would be expected to affect the host more than the parasite, because of the autotrophic character of the host. Furthermore if this diffused light had any effect in the short

period of time during which the plants were in the infection chamber it would be to reduce the photosynthetic processes. The reduced food would probably affect only the last stages of infection, after the germ tube had penetrated the host and the energy of the spore was exhausted or reduced. On the other hand the assumption might be made that there is an alteration in the susceptibility of the host, due to a disturbance of an osmotic or chemical equilibrium. The usual time required for starch to be removed from the plant in total darkness seems to indicate that there would be no actual food shortage.

TABLE 1

Record of infection in total darkness as compared with the light of the headhouse in case of bean and buckwheat and the greenhouse in case of wheat

DATE OF INOCULATION	HOST PLANT	LIGHT		DARKNESS		REMARKS
		Plants infected	Plants wilted	Plants infected	Plants wilted	
July 27, 1917	Bean	3–3	3–3	3–3	3–3	No apparent difference
July 28, 1917	Bean	3–3	3–3	3–3	3–3	No difference
		Plants infected	Total number of spots	Plants infected	Total number of spots	
August 6, 1917	Buckwheat	3–3	28	3–3	28	The number of plants infected and the number of spots are the criteria for the amount of infection
August 28, 1917	Buckwheat	3–3	300	3–3	250	
February 24, 1918	Buckwheat	3–3	230	3–3	295	Under plants infected 3–3 indicates that three out of three plants were infected
January 25, 1918	Wheat	23–24		19–21		
January 28, 1918	Wheat	13–14		13–14		

Some experiments (table 1) were conducted to show whether total darkness as compared with the light of the greenhouse in one case and the light of the headhouse in two other cases alters the total infection of the host plants employed, under the conditions of the experiments. The following pathogens and host plants were used in the experiments: *Colletotrichum lindemuthianum* (Sacc. & Magn.) Bri. and Cav. on bean (*Phaseolus vulgaris* L.); *Ascochyta fagopyrum* Thuen. et Boll. on buckwheat (*Fagopyrum esculentum* Moench.); *Puccinia graminis* Pers. on wheat (*Triticum sativum* Lam.). Both the bean and buckwheat experiments were

conducted in the headhouse mentioned above. In each experiment three plants were placed under a bell jar covered with black paper and three under a jar not so covered. The jars stood on a table before a window. The reason for using the headhouse instead of the greenhouse was that in the latter, during the time in which the experiments were running, the sunlight became so intense at times that under the high humidity of the bell jars the plants were liable to injury. The wheat experiments were performed in the greenhouse during the winter months when the sunlight was not so intense; in fact, cloudy weather prevailed most of the time. The other conditions of the wheat experiments were the same as those mentioned above except that there were more plants used. The experiments were repeated in each case and were run for twenty-four hours, after which the plants were removed to the greenhouse, where they remained until infection became evident. The temperature range was largely between 70 and 80° F. The results are represented in table 1.

It seems fairly safe to conclude from these experiments that light in the infection chamber is not a limiting factor in case of the plants used. It is possible, however, that at the border temperatures and humidities light may manifest itself as a limiting factor.

The carbon dioxide relation

When plants are placed in a closed chamber there is an accumulation of carbon dioxide whenever it is not used up by photosynthesis. The extent of this accumulation depends upon the tightness of the chamber and the amount of circulation provided. The question arises as to whether the concentration of the carbon dioxide becomes sufficiently great in the infection chamber to become deleterious to the host and parasite. If there is an injurious effect, it is possible that the effects are the same in both host and parasite, in which case there probably would be no change in the number of infections. There would be a greater accumulation of carbon dioxide at the higher temperatures, at least until the optimum for respiration was reached, and consequently the effects would be more serious than at low temperatures.

The chambers were not perfectly air-tight. This was indicated by the fact that whenever the electricity was cut off from the heating coils the fall in temperature was sufficiently rapid to show some interchange of air between the inside and outside of the chamber. The greater the differences in temperature on the inside and outside, the greater would be the exchange consequently the tendency for accumulation of CO_2 at high temperatures would be compensated for (at least in part). It would seem therefore that the source of error from carbon dioxide injury would be slight if not negligible.

Influence of sudden change of temperature

When the host plant and pathogen are introduced into the infection chamber they are subjected to a more or less sudden change of temperature, especially when working at low temperatures.

A number of investigators have studied the influence of a sudden change of temperature upon growth in flowering plants, with contradictory results. Sachs (26) and Pedersen (22) conclude that the growth curve follows closely that of temperature. Koeppen (15), Askenasy (3), True (30), Price (23), and Lehenbaur (16) claim that the change itself has a temporary effect, the time varying from one-half to three hours, depending upon the investigator and the amount of change. The evidence seems to be in favor of the latter conclusion. How much this temporary effect may influence infection is not known. Eriksson (9) exposed aeciospores of *Puccinia graminis* to a temperature of 3°C. for two hours and then raised the temperature to about 20°C. He claims that such a change has a beneficial effect and increases the percentage of germination. Melhus (21) found that intermittent temperatures, whether changing from high to low or vice versa, tend to slightly check germination, but suggests that the small variation may be due to experimental error.

Duff (6) found that urediniospores of *Cronartium ribicola* F. de Wal. (which become less viable with age and lose their power of germination in four weeks) which were placed in a refrigerator two weeks after collection germinated only in a small percentage, but a reduction in temperature stimulated a large increase in germination. Spores subjected to a sudden change of temperature three weeks after being collected were stimulated to a slight degree to germinate.

The control of temperature and humidity

On the whole, with the size of the chambers employed the temperature can be kept within a variation of 1°F. The constancy of the temperature is greatly facilitated by the double chamber arrangement with two heating systems and by the use of fans both in the inner and outer chambers.

The temperature control was limited by outside conditions. The chambers were situated in a potting room of a greenhouse where it was possible to maintain a fairly low uniform temperature during the winter. The temperature of the room could be altered by ventilation and the use of steam radiators. This arrangement was sometimes convenient when working at higher temperatures.

The control of humidity was accomplished by means of open pans of

water or saturated salt solutions in combination with temperature manipulations.

Humidities above 95 per cent were difficult to attain whenever the temperature on the inside of the chambers was much higher than that of the outside air, because of inequalities in temperature in the outside chamber. This difficulty was partly overcome by the use of an electric fan and by placing beakers of water on the heating coils. A device was developed during the later stages of the investigation by which it was possible to maintain a saturated condition of air. Instead of using the air heating coils as a source of heat a water heating coil was placed in an evaporating pan containing water, thus insuring a slightly higher temperature of the evaporating surface than of the air and consequently a saturated atmosphere.

Whenever a lower humidity than 95 per cent was desired saturated salt solutions were used. An excess of salt insured a definite vapor pressure at a given temperature and hence a constant humidity. The wide range of vapor pressure of saturated salt solution made it possible to obtain almost any humidity desired.

It is not possible to predict the exact humidity that will result from a given saturated solution. First, because the vapor pressure of the majority of saturated solutions has not been worked out for the various temperatures; second, the vapor pressure of the entire system is altered by the introduction of plants. The leaf surface presents an evaporating surface very near that of pure water, tending to increase the humidity of the system. However, as soon as the system comes to an equilibrium, the humidity becomes constant. It is possible by the inspection of the vapor pressure of the various salts at a given temperature to predict what salt to employ in order to obtain an alteration in humidity in the desired direction. The humidities obtained from the various salts vary in the same direction as the vapor pressures of those salts. Some of the salts used are as follows:—Potassium sulphate with a vapor pressure of the saturated solution of 17.21 mm. mercury at 20°C., Barium chloride V.P. at 20°C. 15.45, Sodium nitrate V.P. at 20°C. 13.7 mm., Cadmium chloride V.P. at 20°C. 12.2 mm.

Relative humidity as a unit of comparison

As has been pointed out by Livingston and others, relative humidity is not a satisfactory unit of comparison whenever more than one temperature is employed. Livingston (18) suggests the use of vapor pressure deficit, which equals the difference between the maximum vapor pressure of water vapor at a given temperature and the actual pressure of water vapor in a given space at a given temperature.

METHODS AND MATERIALS

The following pathogens and host plants were employed in these experiments: *Collectotrichum lindemuthianum* (Sacc. & Magn.) Bri. & Cav. on red kidney bean (*Phaseolus vulgaris* L.) *Puccinia graminis* Pers. var. *tritici* Erick on wheat (Triticum), and *Ascochyta fagopyrum* on buckwheat, gray variety, (*Fagopyrum esculentum* Moench.). The fungi employed were all pure line strains to which the respective hosts were susceptible. An attempt was made to secure pure line strains of the host but this could not be done except in the case of wheat.[3]

The bean and buckwheat plants were grown in two inch pots and the wheat in an inch and a quarter pots in a greenhouse with a temperature ranging from 60° F. to 85° F. and relative humidity varying from 60 per cent to 85 per cent.

Plants of the same age were used as far as possible. Some variation was inevitable, however, even under greenhouse conditions. The beans were usually from sixteen to twenty days old, the wheat from seven to ten, and buckwheat from twenty to twenty-four days old. An effort was likewise made to use spores of the same age. Here some variation occurred, due to the necessarily different conditions under which the organisms were grown. Colletotrichum was grown on bean pods, Ascochyta on potato agar, and the spores of *Puccinia graminis* obtained directly from pustules on the host plant.

Twenty pots were used in each experiment, with one plant in each pot, except in case of wheat, where the number of plants varied from three to five. These cultures were divided into five series of four pots each and designated by the following symbols: Ch 1, Ch 2, Ch 3, F, and D. The plants in Ch 1 were taken directly from the greenhouse when the particular experiment was started, and placed in the infection chamber. The purpose of this series was to show whether or not any infection that occurred was due to spores that may have come in contact with the host before inoculation. The remaining four series were sprayed with a spore suspension from an atomizer (except in case of wheat) and used as follows. The plants in Ch 2 were placed in a special chamber at temperatures and humidities known to be favorable for the development of the disease. This procedure was to determine whether the spores were viable and whether infection would take place if conditions were favorable. The plants of Ch 3 were dried immediately by means of an electric fan and left in the greenhouse as a check to show whether infection occurred

[3] The wheat seed for these experiments was furnished by Dr. E. C. Stakman. This strain was given the number 169 by him and was used because of its susceptibility to the attack of *Puccinia graminis*.

in the infection chamber or in the greenhouse. Series F consisted of plants placed in the infection chamber directly after inoculation and covered with a water suspension of spores. In series D the plants were dried at once and placed in the infection chamber. This series was employed to determine whether a film of water over the surface of the plants was essential to infection. Sometimes series D was omitted in the temperature experiments.

TABLE 2

Record of amount of infection on wheat plants by Puccinia graminis tritici at various low temperatures, the humidity being practically constant

DATE OF INOCULATION	PSYCHROMETER READINGS FAHR. SCALE	DEPRESSION OF WET BULB	RELATIVE HUMIDITY	EXTENT OF INFECTION			
				F[1]	Ch. 1[1]	Ch. 2[1]	Ch. 3[1]
				Number of plants infected	Number of plants infected	Number of plants infected	Number of plants infected
December 18, 1917.....	53.0–52.6	0.4°	97.5	12–34[2]	0–17	17–18	0–16
December 19, 1917.....	53.0–52.6	0.4°	97.5	8–28	0–20	14–24	0–16
December 31, 1917.....	52.7–52.2	0.5°	97.0	9–43	0–24	22–25	0–16
December 21, 1917.....	51.7–51.2	0.5°	97.0	23–43	0–18	16–22	0–20
January 3, 1918.....	50.8–50.4	0.4°	97.0	2–30	0–15	18–22	0–14
January 10, 1918.....	49.8–49.75	0.05°	99.0	5–44	0–18	19–20	0–17
December 10, 1917.....	47.2–46.7	0.5°	96.0	0–30	0–16	16–19	0–12
January 6, 1918.....	47.1–46.75	0.35°	97.0	2–44	0–16	19–20	0–16
December 11, 1917.....	47.0–47.0	0.0°	100.0	1–40	0–20	17–25	0–22
January 19, 1918.....	46.85–46.75	0.1°	99.0	1–41	0–22	25–35	0–22
January 22, 1918.....	46.48–46.2	0.28°	98.0	7–35	0–16	27–27	0–16
January 21, 1918.....	45.5–45.3	0.2°	98.0+	5–31	0–17	12–24	0–26
December 14	42.2–42.0	0.2°	98.0+	0–38	0–20	23–23	0–14

[1] An explanation of symbols is given on page 17.

[2] In this table the number of diseased plants is the criterion of infection. 12–34, 0–17, 17–18, 0–16, etc., means that 12 out of 34 plants, 0 out of 17, etc., were infected.

The wheat was inoculated by removing the spores from pustules of diseased leaves by means of a scalpel and spreading them on the wheat leaves. Ch 2 and F were then sprayed with water from an atomizer.

The plants were allowed to remain in the infection chamber for twenty-four hours and were then returned to the greenhouse, where they remained until the disease developed. The time for the development of the disease varied somewhat with the greenhouse conditions, but since the time is influenced little during the infection period it was not considered in recording data. Sufficient time was allowed in each case for any possible infection to become manifest. Bean plants were allowed ten to fourteen days, wheat thirteen to twenty, and buckwheat ten to fifteen days.

An electric fan was placed in the greenhouse in such a position as to blow a current of air between and above the plants in order to prevent the accumulation of higher humidities immediately around the plants. This procedure was found necessary in some instances to prevent infection of buckwheat. The bean and wheat never showed any tendency to the development of the diseases in the greenhouse. In one instance Ch 3 plants showed infection in case of wheat.

TABLE 3

Record of infection on buckwheat plants by Ascochyta fagopyrum at various low temperatures, the humidity remaining practically constant

DATE OF INOCULATION	PSYCHROMETER READINGS FAHR. SCALE	DEPRESSION OF WET BULB	RELATIVE HUMIDITY	EXTENT OF INFECTION[1]					
				F		Ch. 1	Ch. 2		Ch. 3
				Number of plants infected	Total number of lesions	Number of plants infected	Number of plants infected.	Total number of lesions	Number of plants infected
December 21, 1917	59.50–59.15	0.35°	98.0	7–8	52	0–4	4–4[2]	Numerous	0–4
December 22, 1917	56.70–56.10	0.6°	96.0	0–8	0	0–4	4–4[3]	43	0–4
December 19, 1917	56.10–55.40	0.7°	95.5	2–9	4	0–4	4–4	55	0–4
January 14, 1918...	54.25–54.18	0.07°	99.0	1–8	1	0–4	4–4	60	0–4
January 7, 1918...	53.25–53.00	0.25°	98.5	1–8	1	0–4	4–4	20	0–4
December 11, 1917	48.40–48.00	0.4°	97.0	0–8	0	0–4	4–4	32	0–4
January 22, 1918...	46.48–46.1	0.38°	97.0	4–8	15	0–4	4–4	100	0–4
January 21, 1918...	45.60–45.35	0.25°	98.5	1–8	3	0–4	4–4	150	0–4
December 13, 1917	42.80–42.60	0.2°	98.5	0–8	0	0–4	4–4	Numerous	0–4
December 10, 1917	41.70–40.65	1.05°	92.0	0–6	0	0–4	4–4	36	0–4
December 14, 1917	38.00–37.80	0.2°	98.5	0–8	0	0–4	4–4	All dead	0–4

[1] Two methods of measuring the amount of infection are employed in this table, for example, in column 1 under F the number of diseased plants is used as a basis, while in column 2 the total number of lesions occurring on all the plants marked F are given.

[2] All plants were wilted.

[3] Infection on primary leaves only, 3 plants wilted, one leaf of remaining plant wilted.

Influence of low temperature upon infection of wheat

From table 2 it will be seen that wheat can become infected by *Puccinia graminis* at a temperature as low as 45.5° F. but the infection is very slight and rapidly decreases at temperatures below 45.5° F. In the single experiment run at 42° F. there was no infection. This experiment should

TABLE 4

Record of infection on bean plants by Colletotrichum lindemuthianum at various low temperatures, the humidity remaining constant

DATE OF INOCULATION	PSYCHROMETER READINGS FAHR. SCALE	DEPRESSION OF WET BULB	RELATIVE HUMIDITY	EXTENT OF INFECTION					
				F		Ch 1	Ch 2		Ch 3
				Number of plants infected	Description of infection	Number of plants infected	Number of plants infected	Description of infection	Number of plants infected
January 28, 1918.....	63.8–63.6	0.2°	98.5	8–8	1 plant wilted, 40 per cent of veins colorized, lesions mostly large, 3 to 4 cm. in length	0–3	4–4	3 leaves wilted, 60 per cent coloration	0–4
January 30, 1918.....	62.9–62.5	0.4°	97.3	7–8	1 plant wilted, 1 leaf of each of 2 other plants wilted, 40 per cent coloration, lesions large	0–3	4–4	All plants wilted	0–4
January 21, 1918.....	61.6–61.2	0.4°	97.3	1–8	1 lesion	0–4	4–4	3 plants wilted, 1 leaf of remaining plant wilted, 5 lesions on remaining leaf	0–4
January 22, 1918.....	59.7–59.1	0.6°	96.0+	3–8	22 lesions	0–4	4–4	2 plants wilted, lesions numerous. Lesions 1–2.5 cm. in length	0–4

January 25, 1918.....	61.3–60.6	0.7°	96.0	0–8		0–4	4–4	1 plant wilted, 1 leaf of each of 2 remaining plants wilted, 40 per cent coloration of remaining leaves	0–4
January 17, 1918.....	59.1–58.6	0.5°	97.0	0–8		0–4	4–4	2 leaves wilted, 1 additional leaf wilted. Lesions large, 2 to 4 cm. long. 33 additional lesions	
December 31, 1917...	57.9 –57.3	0.6°	96.0	3–8	Infection on 2 plants limited to secondary leaves (11 lesions), 12 lesions on primary leaves of third plant	0–4	4–4	All the plants wilted	0–4
January 8, 1918.....	54.85–54.7	0.15°	98.8	0–8		0–4	4–4	All the plants wilted	0–4
January 7, 1918.....	53.3–53.1	0.2°	98.5	0–8		0–4	4–4	3 plants wilted. Fourth plant partially wilted	0–4

at least have been duplicated but the low temperature did not prevail at the time. However, the humidity was very favorable and the infection between this point and 50° F. was very slight. It seems therefore that 45° F. is near the lower limit of infection. This point is only about 9° F. above the lowest temperature at which Johnson (13) was able to obtain germination of spores of *Puccinia graminis*.

The amount of infection rises rapidly from within a few degrees of the lower limit to almost a fair average for the higher temperatures, indicating that there is no definite optimum temperature for infection. These results correspond to those obtained by Johnson (13) for germination of spores of *Puccinia graminis*. He found no definite optimum temperature when percentage germination was used as a basis for measuring the amount of germination.

Influence of low temperatures upon infection of buckwheat by Ascochyta fagopyrum

No infection was obtained in buckwheat below 45.5° F (table 3). Another experiment at 42° F. and at high humidity should have been conducted as a further check upon the lower limit but the outside temperature was not sufficiently low to do so. Some variation in the amount of infection between 45° F. and 59° F. will be noted, and even an absence of infection in some cases. An observation of a certain phenomenon in connection with spore germination of the pathogen suggests a possible explanation of this variation. At times, and for reasons unknown, the fungus produced one-celled spores. Whether these spores are merely immature spores is not known, because old cultures sometimes contain them. These spores do not germinate nearly as well as the two-celled spores. At higher temperatures, however, they seem to produce infection. It is possible that these spores may fail to produce infection as the temperature becomes less favorable. This problem needs to be solved.

Low temperatures and infection of bean by C. lindemuthianum

From table 4 it will be seen that the lower limit for infection of bean by Colletotrichum is 57° F. where the plants remain in the infection chamber for twenty-four hours. It is possible that if this time were extended, a lower limit might be obtained.

The rise in the amount of infection here as in case of wheat and buckwheat is rapid. Excellent infection was secured at 63° F.

Infection of wheat at higher temperatures by P. graminis tritici

The highest temperature at which *Puccinia graminis* will produce infection in wheat (table 5) is 80° F., at least under the conditions of the experiment. This temperature is 7.8° F. below the maximum at which the spores will germinate. It is possible that in a saturated atmosphere this temperature might be raised. It seems probable, however, that the highest temperature at which infection will take place is below the maximum for germination.

TABLE 5

Record of infection on wheat plants by Puccinia graminis at various high temperatures, the humidity remaining practically constant

DATE OF INOCULATION	PSYCHROMETER READINGS FAHR. SCALE	DEPRESSION OF WET BULB	HUMIDITY READINGS	EXTENT OF INFECTION[1]				
				F	D[2]	Ch. 1	Ch. 2	Ch. 3
				Number of pots in which infection occurred	Number of pots in which infection occurred	Number of pots in which infection occurred	Number of pots in which infection occurred	Number of pots in which infection occurred
August 25, 1917	82.4–81.70	0.7°	97.0+	0–4	0–4	0–4	4–4	0–4
September 3, 1917	82.0–81.30	0.7°	97.0+	0–4	0–4	0–4	4–4	0–4
August 28, 1917	81.5–81.10	0.39°	98.5	0–4	0–4	0–4	4–4	0–4
September 28,1917	80.8–80.00	0.8°	97.0	0–4	0–4	0–4	4–4	0–4
September 24, 1917	80.0–79.10	0.9°	96.0+	0–4	1–4	0–4	4–4	0–4
September 27, 1917	80.0–79.00	1.0°	96.0	1–4	0–4	0–4	4–4	0–4
September 29, 1917	78.0–77.00	1.0°	96.0	1–5	1–2	0–4	4–4	0–4

[1] In these experiments the number of plants diseased was not counted (there being 3 to 5 plants in each pot), but the number of pots in which infection occurred was used as basis of measurement.

[2] Explanation of symbols is given on page 17.

Infection of bean at higher temperatures by C. lindemuthianum

The highest temperature at which infection took place in bean was 80° F. (table 6). With both wheat and bean a large number of experiments were run at temperatures above 80°. The increase in the number of plants infected was rapid as the temperature was lowered. The range covered is not sufficient to show the same decided increase in the amount of infection. One finds this suggestion, however, in the data.

This maximum temperature for infection falls 7.8° F. below the temperature at which Edgerton finds Colletotrichum to grow in culture media.

TABLE 6

Record of infection on bean plants by Colletotrichum lindemuthianum at various high temperatures, the humidity remaining practically constant

DATE OF INOCULATION	PSYCHROMETER READINGS FAHR. SCALE	DEPRESSION OF WET BULK	RELATIVE HUMIDITY	EXTENT OF INFECTION							
				F		D		Ch 1	Ch 2		Ch 3
				Number of plants infected	Description of infection	Number of plants infected	Description of infection	Number of plants infected	Number of plants infected	Description of infection	Number of plants infected
August 6, 1917	83.3 –82.6	0.7°	97	0–4		0–4		0–4	4–4	All plants wilted	0–4
August 7, 1917	83.25–82.75	0.5°	98	0–4		0–4		0–4	4–4	All plants wilted	0–4
August 13, 1917	83.3 –82.5	0.8°	96+	0–4		0–4		0–4	4–4	All plants wilted	0–4
August 25, 1917	82.3 –81.7	0.6°	98–	0–4		0–4		0–4	4–4	Infection fair	0–4
September 3, 1917	82.0 –81.3	0.7°	97	0–4		0–4		0–4	4–4	All plants wilted	0–4
August 28, 1917	81.5 –81.1	0.4°	98+	0–4		0–4		0–4	4–4	2 leaves partly wilted, coloration throughout veins	0–4
September 17, 1917	81.0 –80.9	0.1°	99+	2–4	In 1 plant 2 spots on secondary leaves, 1 spot on primary leaf. Second plant large number spots on secondary leaves. Several large spots on 1 leaf	0–4		0–4	4–4	Some dead areas. All the veins colorized	0–4

September 24, 1917..	80.4 –79.1	1.3°	95	1–4		1–3	2 spots on secondary leaves. 1 on primary	0–4	4–4	Infection medium. 4 leaves partly wilted	0–4
September 26, 1917..	80.0 –79.0	1.0°	96	2–4	8 lesions on primary leaves	3–4	1 case infection confined to secondary leaves. On other 2 plants infection on primary leaves. 1 leaf 1 spot. Other plant several lesions	0–4	4–4	All wilted	0–4
September 28, 1917..	80.8 –80.0	0.8°	97	1–4	7 small lesions	1–4	2 lesions on secondary leaves	0–4	4–4	3 completely wilted, fourth badly infected	0–4
September 29, 1917..	78.0 –77.0	1.0°	96	4–4	Lesions largely confined to secondary leaves	4–4	Largely confined to secondary leaves	0–4	4–4	3 plants completely wilted	0–4

Infection of buckwheat at higher temperatures by Ascochyta fagopyrum

The upper limit for the growth of buckwheat appears to be about 100° F. (table 7). Most of the plants collapsed after having been in the infection chamber at this temperature for twenty-four hours. Yet in one instance typical Ascochyta lesions appeared on plants that survived. I have germinated the spores of the fungus at a temperature of 106° F. The maximum temperature for germination has not been determined. Some ex-

TABLE 7

Record of infection of buckwheat by Ascochyta fagopyrum at various high temperatures and within the humidity range at which infection takes place

DATE OF INOCULATION	PSYCHROMETER READINGS FAHR. SCALE	DEPRESSION OF WET BULB	RELATIVE HUMIDITY	EXTENT OF INFECTION							
				F		D		Ch. 1	Ch. 2		Ch. 3
				Number of plants infected	Total number of lesions	Number of plants infected	Total number of lesions	Number of plants infected	Number of plants infected	Total number of lesions	Number of plants infected
			per cent								
March 12, 1918....	100.0–100.0	0°	100.0	2–11[1]	2	—	—	0–4[2]	4–4	37	0–4
March 13, 1918....	100.0–100.0	0°	100.0	0–8[3]	0	—	—	0–4[4]	4–4	119	0–4
August 3, 1917.....	97.7– 95.2	2.5°	91.5	1–4	Several	1–4	Few	0–4	4–4	Numerous	2–4[5]
September 27, 1917	93.3– 90.8	2.5°	91.5	1–4	1	1–4	3	0–4	4–4	90	0–4
September 28, 1917	92.6– 90.3	2.3°	92.0	1–4	5	1–4	2	0–4	4–4	24	0–4
September 6, 1917	91.0– 88.0	3.0°	89.0	3–4	10	1–4	2	0–4	4–4	117	0–4

[1] Four out of 11 plants were dead. Remaining were all injured.

[2] All 4 plants were dead at end of infection period.

[3] Seven out of 8 plants were dead.

[4] Two plants dead; 2 remaining plants injured.

[5] These plants show infection but they were at the end of the greenhouse, where there was dropping from the roof.

periments were conducted at temperatures above 100° F., but the plants always died.

The limits of temperature at which infection by Ascochyta occurred in buckwheat were wider than in wheat and bean. In the latter two the maximum temperatures for growth are higher than for infection. It is possible, at least in case of beans, to grow them at temperatures unfavorable for the fungus and thus escape the losses due to this disease where the other conditions for its development are favorable.

Infection of buckwheat at various humidities by Ascochyta fagopyrum

In table 8 is shown the infection of buckwheat at various humidities, the temperature remaining nearly constant. The lowest humidity at which infection has been observed to take place on buckwheat is 91 per cent. The humidity rises to 94.5 per cent where the plants were dried before placing them in the chamber. It will be noted, however, that considerable infection took place at this humidity. This table not only shows that infection can take place at the temperatures considered, within a

TABLE 8

Record of infection on buckwheat by Ascochyta fagopyrum at various humidities, the temperature remaining practically constant

DATE OF INOCULATION	PSYCHROMETER READINGS FAHR. SCALE	DEPRESSION OF WET BULB	RELATIVE HUMIDITY	EXTENT OF INFECTION							
				F		D		Ch. 1	Ch. 2		Ch. 3
				Number of plants infected	Total number of lesions	Number of plants infected	Total number of lesions	Number of plants infected	Number of plants infected	Total number of lesions	Number of plants infected
November 15, 1917	77.1–76.2	0.9°	96.3	3–4	23	3–4	11	0–4	4–4	32[1]	0–4
November 20, 1917	77.6–76.3	1.3°	95.0+	2–3	12	3–4	17	0–4	4–4	57	0–4
November 13, 1917	78.0–76.0	2.0°	91.0	1–4	2	0–4	0	0–4	4–4	54	0–4
November 8, 1917	78.7–76.9	1.8°	91.5	0–4	0	0–4	0	0–4	4–4	100	0–4
November 27, 1917	77.3–75.2	2.1°	90.6	2–4	4	0–4	0	0–4	4–4	55	0–4
October 4, 1917	77.1–74.5	2.6°	89.0	0–4	0	0–4	0	0–4	4–4	37	0–4
October 8, 1917	77.2–74.7	2.5°	89.0	0–4	0	0–4	0	0–4	4–4	46	0–4

[1] Plant wilted (lesions not counted).

range from 91 per cent to 100 per cent humidity, but that a film of water covering the leaf surface is not essential to infection.

The question may arise as to the possible presence of a film on the leaf surface at such high humidities. It has been observed throughout these experiments that plants placed in the chamber with a film covering the leaf surface are dry when removed at the end of twenty-four hours. Since the chamber is always run at a temperature above that of the surrounding atmosphere, evaporation must always take place because under these conditions saturation is rarely ever reached. The only cases where a condition of saturation has been observed are at the lowest temperatures.

Infection of wheat at various humidities by P. graminis tritici

The range of humidity for infection in wheat (table 9) is a little narrower than it is for buckwheat. The lowest humidity at which infection has been observed is 95 per cent. No infection takes place at 92 per cent and below. The same general difference is observed between the plants with a film and those without. The dry plants require a slightly higher humidity.

TABLE 9

Record of infection of wheat by Puccinia graminis tritici at various humidities, the temperature remaining practically constant

DATE OF INOCULATION	PSYCHROMETER READINGS FAHR. SCALE	DEPRESSION OF WET BULB	RELATIVE HUMIDITY	EXTENT OF INFECTION				
				F	D	Ch. 1	Ch. 2	Ch. 3
				Number of plants infected	Number of plants infected	Number of plants infected	Number of plants infected	Number of plants infected
February 18, 1918	70.0–69.6	0.4°	98+	12–15	15–17	0–27	22–22	0–25
March 7, 1918	68.9–68.4	0.5°	97	5–22	5–17	0–26	14–18	0–17
March 8, 1918	68.2–67.3	0.9°	96	5–16	2–19	0–16	10–15	0–13
February 24, 1918	67.5–66.7	0.8°	96−	8–19	3–16	0–20	28–29	4–24[1]
March 4, 1918	68.9–67.9	1.0°	95	7–16	3–13	0–15	10–11	0–12
March 10, 1918	68.0–67.0	1.0°	95	6–17	0–17	0–18	8–11	0–17
November 17, 1917	68.0–66.5	1.5°	93	0–16	0–15	0–17		0–14
November 22, 1917	68.2–66.7	1.5°	93	0–15	0–14	0–12	12–17	0–14
November 28, 1917	68.5–67.0	1.5°	93	0–15	0–15	0–15	14–18	0–14
November 12, 1917	68.1–65.6	2.5°	88	0–20	0–17	0–18	12–16	0–19
December 3, 1917	68.0–65.3	2.7°	88	0–14	0–16	0–17	11–15	0–13

[1] In this case Ch 3 showed slight infection, the only case ever recorded on wheat.

The temperatures at which the humidities were studied were arbitrarily selected, after considerable preliminary work. These temperatures were thought to be within the limits of the optimum.

Influence of humidity upon infection of bean by Colletotrichum lindemuthianum

The lowest humidity at which infection took place in bean is near that of wheat. The data in table 10 do not show any infection at 95 per cent humidity, but only one experiment was run at this humidity. Negative results were also obtained with wheat at 95 per cent humidity.

TABLE 10

Record of infection by Colletotrichum lindemuthianum on bean at various humidities, the temperature remaining nearly constant

DATE OF INOCULATION	PSYCHROMETER READINGS FAHR. SCALE	DEPRESSION OF WET BULB	RELATIVE HUMIDITY	EXTENT OF INFECTION								
				F		D		Ch 1		Ch 2	Ch 3	
				Number of plants infected	Extent of infection	Number of plants infected	Extent of infection	1	Number of plants infected	Extent of infection	Number of plants infected	
March 16, 1918	68.7–68.3	0.4°	97.0	4–4	Leaves wilting around discolored veins. Many lesions	4–4	Veins colored pink. 150–200 lesions	0–4	4–4	All dead	0–4	
March 24, 1918	69.0–68.5	0.5°	97.0	4–4	1 plant badly wilted. Veins colored 200 lesions	4–4	Veins colored. Leaves wilting. Many lesions.	0–4	4–4	All dead	0–4	
March 20, 1918	67.4–66.8	0.6°	96.6	5–5	50 per cent coloration. 49 lesions	2–4	2 lesions. 1 on each plant	0–4	4–4	2 plants dead. A leaf of each on 2 additional plants wilted. Numerous lesions	0–4	
March 23, 1918	68.2–67.6	0.6°	96.6	3–4	12 lesions on 1 plant. 2 leaves wilted on 2 plants. Also many lesions	4–4	1 leaf partly wilted on each of 2 plants. 2 lesions on 1 plant. Many lesions on other two	0–4	4–4	Leaves covered with lesions. 60 per cent coloration of veins	0–4	
March 22, 1918	69.0–68.2	0.8°	95.8	4–4	2 plants 1 lesion each. 1 plant 108 lesions. 1 plant 167 lesions.	1–4	8 lesions	0–4	4–4	Lesions numerous 70 per cent of veins colored	0–4	
November 23, 1917	68.9–68	0.9°	95.0+	0–4		0–4		0–4	4–4	All dead	0–4	
November 17, 1917	68.0–66.5	1.5°	93.0	0–4		0–4		0–4	4–4	2 plants wilted. 2 partially wilted	0–4	
November 28, 1917	68.5–67	1.5°	93.0	0–4		0–4		0–4	4–4	All wilted	0–4	
December 3, 1917	68.0–65.3	2.7°	86.8	0–4		0–4		0–4	4–4	All wilted	0–4	
December 6, 1917	67.5–64.8	2.7°	86.8	0–4		0–4		0–4	4–4		0–4	

A large number of experiments were run at humidities above 95 per cent. The data given in the table are representative of the results obtained. A large number of experiments were conducted at humidities of 92 per cent and below.

There is a rapid rise in the number and extent of infections from 95 per cent up to 100 per cent. At 97 per cent humidity, the highest humidity given in the table, the amount of infection approaches closely that in Ch 2, where saturation was attained at least part of the time and where the film over the leaf was maintained throughout the infection period due to precipitation because of alterations in temperature. The temperatures in Ch 2 varied largely between 65° F. and 75° F. The same influence of the presence of a film is to be noted as in the wheat and buckwheat.

DISCUSSION AND CONCLUSIONS

Heretofore the study of the effects of temperature upon the relation of parasite to host has been limited largely to the influence of temperature upon the growth of the fungus and the germination of the spores. In a few cases the effects of temperature upon the development and extension of diseased tissue has been studied (Ball (4), Brooks and Cooley (5)). This phenomenon is largely one of growth and seems to obey, in the main, the Van't Hoff law. The growth of the fungus behaves in the same way (Tisdale (29), Brooks and Cooley (5)).

A number of methods have been employed to measure the effect of temperature upon germination, with varied results. In some cases it would seem that all the factors involved were not considered.

The extension of the germ tube and the development of mycelium have been used as a basis for the study of the influence of temperature upon germination and infection (Johnson, E. C. (13), Wiesner (30), Balls (4), etc.). Here one is dealing with a growth phenomenon, and when food is not a limiting factor one would expect the behavior of this phenomenon towards temperature to be the same as found among flowering plants and the growth of fungi in culture media. For every increase of 10°C. (within certain limits) there would be a doubling or trebling of growth in a given time (Tisdale (29), Brooks and Cooley (5), Edgerton (7)).

The time required for germination has been used as a measure of the influence of temperature. The results have been rather uniform, and there has been a general shortening of time with an increase of temperature to a more or less optimum temperature in the same proportion as demanded by the Van't Hoff law (Anderson (1), Hecke (12), Wiesner (31), Ravaz (24), Melhus (21), Shapovalov (27)). Ames (2) obtained varied results with different species. In some cases the optimum is very broad,

while in others the time is shortened with an increase of temperature to a rather definite optimum.

Where percentage germination has been used as a criterion for measuring the effects of temperature, fairly uniform results have been obtained. The optimum, as a rule, is broad, as one would naturally expect if sufficient time were allowed at the lower temperatures for germination to take place. If a shorter time were used different results might be expected. Melhus' (21) results with the spores of *Phytophthora infestans* show a fairly broad optimum (5° to 13°C.) where he used the number of cultures in which germination occurred as a basis of measurement of the temperature effects. It is sharper, however, than that obtained by other investigators. Where he used the percentage germination in the various cultures as a criterion, there was a gradual rise in percentage from 5° to 13°C. He states, however, that there was a variation from 13 to 80 per cent in germination at the optimum. This fact may account for the difference in the two curves. Ames (2) abandoned percentage as a basis of measuring the effects of temperature upon germination because her results were not uniform. Anderson (1) found the percentage germination of the spores of *Cylindrosporium scoparium* Morg. was almost total between 12° and 30°C., ranging between 95 and 100 per cent. Johnson (13) did not obtain a definite optimum temperature for *Puccinia graminis* by percentage germination, there being no uniformity between 9° and 25°C.

From these results it would seem that the number of spores which germinate does not rise with an increase in the temperature to a definite optimum, but that the range at which a large number of spores will germinate is wide. One would expect, then, that there would be a wide range of temperature at which the number of infections that would take place would not vary much if sufficient time were allowed for the spores at lower temperatures to cause infection, providing some other factor did not enter in. This view corresponds to the results of the present experiments (tables 2, 3, and 4). Some experiments were conducted between the temperature limits given in the tables with results which conform to this conclusion. These results have also been confirmed by Ravn and Fromme (pages 11 and 12).

An understanding of this phenomenon is important wherever the number of lesions, such as in leaf spots, fruit spots, etc., is responsible for the chief loss due to diseases. If there were a definite optimum, the number of lesions that would develop would gradually decline as the temperature was lowered from the optimum. The infection phenomenon viewed in this light implies a different attitude towards control measures. Not only must the degree of temperature be considered, but the time to which the host plant is exposed to conditions of infection, in connection with

the number of infections that take place as well as the development and extension of a particular lesion.

Some incidental data obtained in the present investigation in connection with infection of bean by *C. lindemuthianum* near the lower temperature limit indicate that the time element is important. The data point to a lower temperature limit for infection where forty-eight hours were used for an infection period than where twenty-four hours were used.

From the data presented, an interesting relation between host and parasite is brought out. The temperature ranges for host and parasite are not identical in any of the cases. The temperature range for growth of bean and wheat is wider than for the germination of spores and of infection by *C. lindemuthianum* and *P. graminis*. The maximum temperature for infection by the two pathogens is about the same in the time employed (tables 5 and 6) while the lower limit for infection by *P. graminis* (compare tables 2 and 4) is lower than for infection by *C. lindemuthianum*. The upper temperature limit for the growth of bean is higher than for germination of the spores of and infection by *C. lindemuthianum*, which fact has made possible the control of anthracnose in the Southern States. The optimum temperature for the growth of bean is probably higher than that of wheat.

The exact temperature ranges for Ascochyta and buckwheat have not been determined. There is no indication as to which has the wider range. Their ranges do not coincide, because buckwheat is killed at a temperature at which infection takes place and below the maximum temperature for germination of spores of Ascochyta (table 7). These relations are all important in connection with control measures.

The variation in the amount of moisture in the air in different regions is probably important in the distribution of diseases over the earth's surface. The absence of certain diseases in semi-arid and arid regions where agriculture has been practiced for long periods of time may be due in part to the small moisture content of the air.

Seasonal variation in the moisture content of the air plays an important part in determining the amount of disease that may develop.

In the course of the present investigation (compare tables 8, 9, and 10), a variation in the humidity in the air required for infection for the individual plant has been exhibited. Infection occurred at a slightly lower humidity in buckwheat than in case of bean and wheat. As mentioned earlier, it was necessary to provide for circulation of air about the buckwheat plants to prevent infection in the greenhouse. This same provision was found requisite in a few experiments conducted with *Septoria lycopersici* Speg. on tomato. The tendency for infection to take place in the greenhouse was more marked with tomato than with buckwheat.

The degree of humidity in the general environment of the plant may be an inaccurate criterion of the amount of moisture required for infection, at least when there is little air movement. The air movement created by an electric fan over a bench in the greenhouse has been sufficient to prevent infection of buckwheat by *A. fagopyrum* and of tomato by *S. lycopersici* where in its absence infection took place. The higher humidity in the immediate environment of the plant may be of considerable significance in connection with infection in nature.

Just how the spore upon the plant surface obtains sufficient moisture for germination and infection is an unsolved problem. Within certain limits of humidity, that is, where the evaporation is not too great, the spore is able to absorb sufficient water for germination. The absorption may be from the host plant, at first by imbibition and later by osmosis. It is possible that in the depressions of the leaf surface and especially immediately above the stomata a higher humidity prevails which may afford sufficient moisture for germination.

There is a possible relation to hairiness because the juvenile leaves of buckwheat have more hair than the secondary leaves and seem to be infected more readily (the data contained in the tables are from the secondary leaves). The secondary leaves of the bean are more pubescent and seem to be infected more easily at the limiting humidities. The hair would tend to prevent evaporation and increase the humidity at the leaf surface.

SUMMARY

The lower temperature limit for infection of wheat by *Puccinia graminis tritici* is somewhere near 42° F. The amount of infection rises rapidly and at 53° F. it approaches the average for higher temperatures.

The lower temperature limit for infection of buckwheat by *Ascochyta fagopyrum* is about 45° F. There is some variation in infection between this temperature and 59° F., possibly due to the one-celled spores sometimes produced in culture.

The lower temperature limit for infection of bean by Colletotrichum is about 57° F. This limit may be influenced by the time the plants are in the infection chamber.

The upper temperat re limit for infection of wheat is 80° F.

The maximum temperature for infection of buckwheat by Ascochyta is about 100° F. At this temperature buckwheat plants are injured or killed.

The upper temperature limit for infection of bean is 80° F. With the decrease of temperature there is a rapid increase in the number of plants infected.

There seems to be no definite optimum temperature for infection in the hosts and parasites used where the number of infections is used as a measure of the amount of infection and sufficient time is allowed for the fungi to establish a relation with the hosts.

The range of humidity for infection of buckwheat varies between 90 per cent and 100 per cent. Where the plants are dried off before being placed in the infection chamber, it varies between 94.5 per cent and 100 per cent.

The humidity range for infection of wheat is between 92 per cent and 100 per cent. The lowest humidity at which infection has taken place is 95 per cent. The range for the dried plants is a little narrower.

The range of humidity for infection of bean lies between 92 per cent and 100 per cent.

A film of water covering the leaf surface is not essential to infection.

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SOME POTENTIAL PARASITES OF THE POTATO TUBER[1]

M. SHAPOVALOV

WITH PLATES II AND III AND TWO FIGURES IN THE TEXT

The major portion of the fungous flora is composed of organisms whose connection with any known disease has not been shown. Such fungi are generally spoken of as saprophytes. The application of this term, however, should often be regarded as an expression of our incomplete knowledge of the microorganisms so grouped rather than as a correct naming of their actual characteristics. The possibilities of aggressiveness on the part of saprophytic fungi and the significance of the constant association of some of them with certain higher plants have not received an exhaustive and adequate study. Moreover, there is some evidence that certain organisms regarded as saprophytes are endowed with what may be termed a "potential parasitism." Though their activities under ordinary conditions may be restricted to the decomposition of dead material, there may arise a combination of circumstances which will enable them to invade living tissues. The degree of their virulence in such a case will naturally vary with the change of environment.

Edson and the writer[2] have recently demonstrated this phenomenon with regard to potato-stem lesions. When uninjured potato plants were inoculated with pure cultures of various fungi, among which were several organisms unsuspected of parasitism, the latter produced as severe lesions as those caused by such well recognized parasites as Fusarium and Rhizoctonia. And yet, they have never been obtained in prevailing numbers in isolation plates from diseased field material, a fact which seems to indicate that under the existing natural conditions they are probably of minor importance.

This paper presents an account of inoculation experiments on potato tubers with pure cultures of *Penicillium oxalicum*, *Aspergillus niger* and *Clonostachys rosea*. These fungi are not generally considered to be parasitic on potato tubers, although not infrequently they may be found on them either in wounds or in decaying areas attributed to other organisms.

[1] The writer is indebted to Dr. H. A. Edson for many valuable suggestions and criticisms of this paper.

[2] Edson, H. A., and Shapovalov, M., Potato-stem Lesions. In Jour. Agri. Res. **14**: No. 5, pp. 214–219, pls. 24–26, Washington, D. C. 1918.

The results of the experiments show the possibility of an actual parasitism on the part of these fungi.

Methods of inoculation. All inoculations, except when specifically mentioned otherwise, were performed with Irish Cobblers, which were grown in Aroostook County, Maine, and stored during the winter months in Washington, D. C. The tubers were washed and disinfected in a 0.5 per cent formaldehyde solution. Wounds in different series were made in one of four ways (a) needle pricks, (b) cork-borer channels, (c) deep scalpel-incisions, and (d) shallow scratches on the surface. Mycelium two to three days old produced from spores in broth or on fresh potato-agar plates, which gave excellent results, was employed as inoculum in most of the experiments. The mycelium was inserted in the wounds, and the tubers were immediately placed in stone jars with one layer of blotting paper on the bottom and one on the top. The paper was previously soaked for a few minutes in boiling water and cooled down to the room temperature. The jars were kept in a laboratory cabinet at a temperature of about 25°C. throughout the period of incubation. The different groups of the inoculated material were kept in separate jars.

FIG. 1. A CAMERA LUCIDA DRAWING OF *P. oxalicum*, CULTURE NO. 1006

Showing conidiophores, verticils, sterigmata and conidia in various combinations. About × 420.

Penicillium oxalicum Currie and Thom[3]

(Culture no. 1006, text figure 1)

This Penicillium was isolated by the writer in January, 1918, from a brownish area at the stem end of a potato tuber. The material had been shipped from Maine the previous season and stored in barrels at Arlington Farm, Va. The same fungus was isolated from an Irish Cobbler tuber sent from Maine by mail in the early part of June, 1918. This tuber had a brown patch extending a few millimeters into the flesh with a moderate amount of spores on the surface. As no significance was attached by the writer to the occurrence of Penicillium on the potato tubers prior to this work, no data have been collected regarding the real importance of *P. oxalicum* in nature. In artificial inoculations this fungus caused a

[3] The writer's culture was identified by Dr. Charles Thom and Miss Margaret B. Church of the Bureau of Chemistry, U. S. Department of Agriculture.

distinct progressive rot. Infection took place quite readily, leading to a characteristic soft, dark-brown decay. Not infrequently a zonation of darker and lighter areas developed. Spores were formed in abundance over the surface of the diseased areas.

Six tubers were inoculated in shallow wounds, two to each tuber. In two weeks every inoculation gave positive results, the decaying areas reaching 15 mm. in depth and 20 mm. in diameter. A small amount of white mycelium was formed inside these areas (plate II, *A*). The tubers were kept in the jars four additional weeks, but the further progress of the decay was considerably slower. In another series four tubers were inoculated in deep scalpel-wounds and a severe soft decay resulted, averaging 25 to 35 mm. in diameter after three weeks. Hollowed spaces lined with white mycelium developed in the center of the decay (plate II, *B*). The further progress of the rot was much less rapid. The ability of the fungus to penetrate the uninjured surface of the tubers was also tested. Four tubers pricked with a needle and five unpricked were placed in a stone jar and dusted abundantly with the spores of *P. oxalicum*. In three weeks a progressive rot developed in two of the pricked tubers, destroying from one-third to one-half of their substance. No rot could be seen on the remaining pricked tubers nor on any of the uninjured ones, except that the young sprouts in many instances were affected and killed, with a profuse fruiting of the fungus on their surfaces. Reisolations in each series yielded pure cultures of *P. oxalicum*.

An inoculation experiment was also carried on with new tubers of the Irish Cobbler variety grown at Arlington Farm, Virginia, and used three weeks after digging. Seven tubers each bearing two shallow wounds were inoculated with a few days' growth of the fungus and two weeks later eleven wounds out of the fourteen developed into the characteristic decaying areas. The size of the latter varied from 6 to 17 mm. in depth and from 12 to 30 mm. in diameter. The control tubers remained sound. Reisolation cultures were not made from this material but the decay was typical of *P. oxalicum* in all respects.

On the underground portions of the growing potato plants this fungus, when artificially inoculated without wounding, produced dark depressed lesions in some cases and only a mild infection in others.

The writer had also two other undetermined species of Penicillium from potato tubers (cultures nos. 1007 and 1008). They were tested at the same time, by the same method and under the same conditions as *P. oxalicum* but in no case did the rot occur, although the material was incubated nearly two months.

Aspergillus niger Van Tiegh[4]

(Culture no. 1001)

The fungus was isolated in December, 1917, from spores present in abundance in deep, dry pits of potato tubers sent from New Jersey for identification. The resemblance of these pits to "deep-scab" suggested that *A. niger* on this material, was probably secondary. Similar material was under the writer's observation in 1915 during his connection with the Maine Agricultural Experiment Station. These latter specimens were sent to Dr. W. J. Morse from a point in Vermont as samples of a peculiar "deep scab." No instance of pure Aspergillus rot occurring in nature has been seen by the writer. The results of the artificial inoculations were somewhat variable. While some tubers remained uninfected a quite destructive decay developed in others of the same lots. The affected area was yellow to light-brown in color, somewhat spongy in texture, frequently with beaded spongy strings of mycelium in the center of the decay. Fruiting was abundant on the surface and in some cases also inside.

Four tubers were inoculated in deep scalpel-wounds and three weeks later two of them showed a large area of decay (plate II, *D*). The other two remained uninfected. Another lot of six tubers was inoculated in shallow surface wounds and two weeks later four of them showed decaying areas averaging 15 mm. in depth and 20 mm. in diameter (plate II, *C*). The tubers were kept two weeks longer and the rot in the four affected tubers progressed to about the same degree as in the preceding test. A small amount of rot was evident in one of the two previously uninfected tubers, but one tuber still remained sound. The fungus was recovered in pure cultures from the areas showing rot. In a third series, four tubers covered with needle pricks and five uninjured ones were smeared with the spores of the fungus. In no case did the rot develop sufficiently to be observable macroscopically.

Seven new tubers of the variety Irish Cobbler grown at Arlington farm were wounded superficially and inoculated three weeks after digging, mycelial growth of a few days being employed as inoculum. Only five wounds out of fourteen showed decay ranging from 5 to 10 mm. in depth and from 10 to 28 mm. in diameter.

A few trial inoculations with this fungus, of unwounded potato stems below ground, resulted in a slight browning of the portions where the culture was applied but distinct lesions were not obtained.

[4] The writer's identification was verified by Dr. Charles Thom of the Bureau of Chemistry, U. S. Department of Agriculture.

Clonostachys araucaria var. *rosea* Preuss[5]

(Culture no. 401, text figure 2)

This fungus was repeatedly isolated by the writer in 1916 and 1917 from stem lesions and from decaying potato tubers in Maine, from seed tubers planted in the greenhouse in Washington, D. C., and also, in 1918.

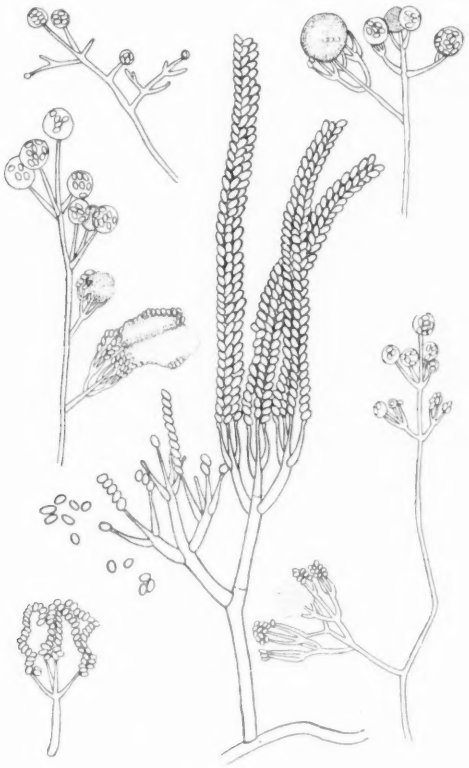

FIG. 2. A CAMERA LUCIDA DRAWING OF *C. rosea*, CULTURE NO. 401

Showing a diversity of spore groups as produced in potato-agar plates. The larger figure in the center about × 500, and the remainder about × 250.

[5] The writer's culture appears to correspond closely to Saccardo's description of *C. araucaria* var. *rosea* Preuss. (Sylloge, **4**: 165). Characteristic spikes are always present along with a variety of other spore groups due, probably, to the unnatural conditions of artificial cultures, since the results remained constant after several replatings in which high dilutions of spores were employed. This fungus was used in the previous inoculations of the potato stems as *Clonostachys* sp. (Edson and Shapovalov, l.c.)

from stem-end discolorations of the tubers grown at Arlington Farm, Va. About 100 tubers including Irish Cobblers, Green Mountains, Bliss Triumph, and Eureka varieties and a number of growing stems were inoculated in series at different times with uniformly positive results. Both mature and green tubers showed practically equal susceptibility. It should be stated, however, that all the successful inoculations of the tubers were those which were made in more or less deep incisions while the inoculations in shallow wounds usually produced no effect. Inoculations on unwounded stems produced light brown lesions, irregular in outline and somewhat depressed.

In tubers the progress of the decay was very slow, the diameter of the diseased areas three to four weeks after inoculation averaged only about 0.5 cm. The appearance and the nature of the rot is very characteristic. The host tissues killed by the fungus form dark, compact, dry layers, adjacent to the healthy tissues, accompanied almost invariably by cavities in the center of infection. Later on, as the rot progresses, other layers of dead tissue and other cavities are formed (plate II, *E*). When the inoculum is placed in the hole made with a cork-borer and the plug is replaced, the destruction usually takes place at the bottom of the hole, the cavity gradually enlarging in size, while the outer portions of the tuber and the plug frequently remain unchanged (plate III, *A*). In a number of cases the fungus penetrated the cambium layer and then spread much beyond the area invaded in the parenchyma (plate II, *F*). On the other hand, numerous attempts to induce invasion of the vascular system of growing stems with subsequent symptoms of wilt, were unsuccessful whether the inoculum was applied to the soil, to the seed tubers, or to the normal, wounded stems themselves. However, when stems were cut off and immersed in a suspension of spores, they wilted and withered after three days while the check stems kept in water remained green and turgid for a week or longer. Browning of the vascular system was present to some extent in the wilted stem and the fungus was recovered therefrom. It was reisolated also a number of times from the artificially induced tuber-rot.

Similar experiments were carried on with an unidentified species of Verticillium (Acrostalagmus? Culture no. 411), which gave essentially the same results, except that the amount of rot was notably smaller (plate III, *C* and *D*).

In order to obtain a standard of comparison for estimating the amount of damage caused by the fungi discussed in this paper tubers were simultaneously inoculated with these organisms and with *Fusarium radicicola*, unquestionably a serious wound-parasite of the potato. The inoculum was introduced in deep scalpel-incisions similar to those employed in the other

series. The amount of rot produced in the period of three weeks is shown in plate III, *B*. It can be seen at once that the largest area of decay produced in any one individual tuber by *A. niger* nearly equals that caused by *F. radicicola*, while *P. oxalicum* falls somewhat below the mark set by that organism and *C. rosea* lags behind by a far greater amount. On the other hand, considering the per cent of infected wounds and tubers, we find that under the conditions of the above experiments the damage caused by *A. niger*, in the aggregate, is much less serious than that caused by *P. oxalicum*. Thus when the inoculum was introduced in the wounds the percentages of infection with *A. niger* were 50, 83, and 35, while in the corresponding series with *P. oxalicum* they were 100, 100 and 78. In case of tubers pricked with a needle and dusted with the spores of these fungi, *P. oxalicum* caused infection of two out of four tubers while *A. niger* produced no rot whatever.

The characteristic appearance of the checks both with deep and with shallow wounds in all the above experiments is illustrated in plate III, *E* and *F*.

The foregoing experiments indicate that there are unrecognized dormant enemies of our crops which hitherto have received scant study but which deserve greater attention. Their economic importance at the present time may not be great, but their potentialities as demonstrated by the laboratory tests, are quite menacing. The organisms possessing such tendencies and abilities may well become active agents of destruction in nature. It is not imprbable that such transitions to parasitism have taken place in the past and that with a better knowledge of saprophytic microorganisms we shall be able to see the real significance of some so-called "new" diseases.

In this connection it will be of interest to note a statement made by P. J. Anderson in his recent paper on *Cylindrocladium scoparium* Morg.,[6] namely, that "previous to 1917 this fungus had not been reported as a parasite." Of course, there are no means at our disposal which would enable us to disclose whether the parasitic activities of this organism existed in the distant past or not. However, it is quite possible and probable that its aggressive faculty has developed with the progress and extension of the greenhouse culture of roses. The very fact that it causes a serious disease of *greenhouse* roses is quite noteworthy.

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[6] Anderson, P. J., Rose Canker and its Control. Mass. Agr. Exp. Sta. Bul. 183, 11–46, pls. I–III. 1918.

PLATES

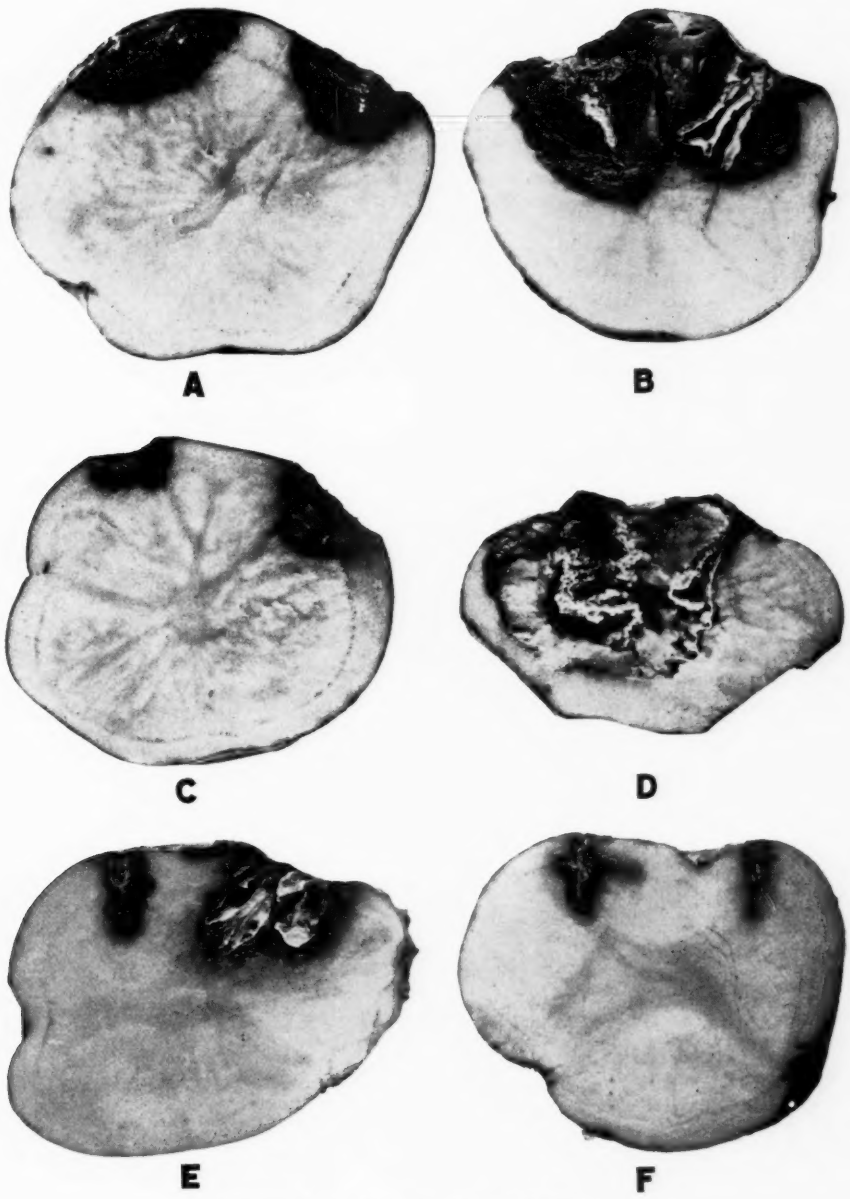
PLATE II

(Slightly reduced)

A and *B*. Tubers inoculated with *Penicillium oxalicum:* A, in shallow wounds, two weeks after inoculation; and *B*, in deep scalpel-wounds, three weeks after inoculation.

C and *D*. Tubers inoculated with *Aspergillus niger;* time and characters of wounds respectively the same as for *A* and *B*.

E and *F*. Tubers inoculated with *Clonostachys rosea* in deep needle-pricks: *E*, maximum amount of rot eight weeks after inoculation; *F*, average amount of rot four weeks after inoculation.



SHAPOVALOV: POTATO TUBER PARASITES

PLATE III

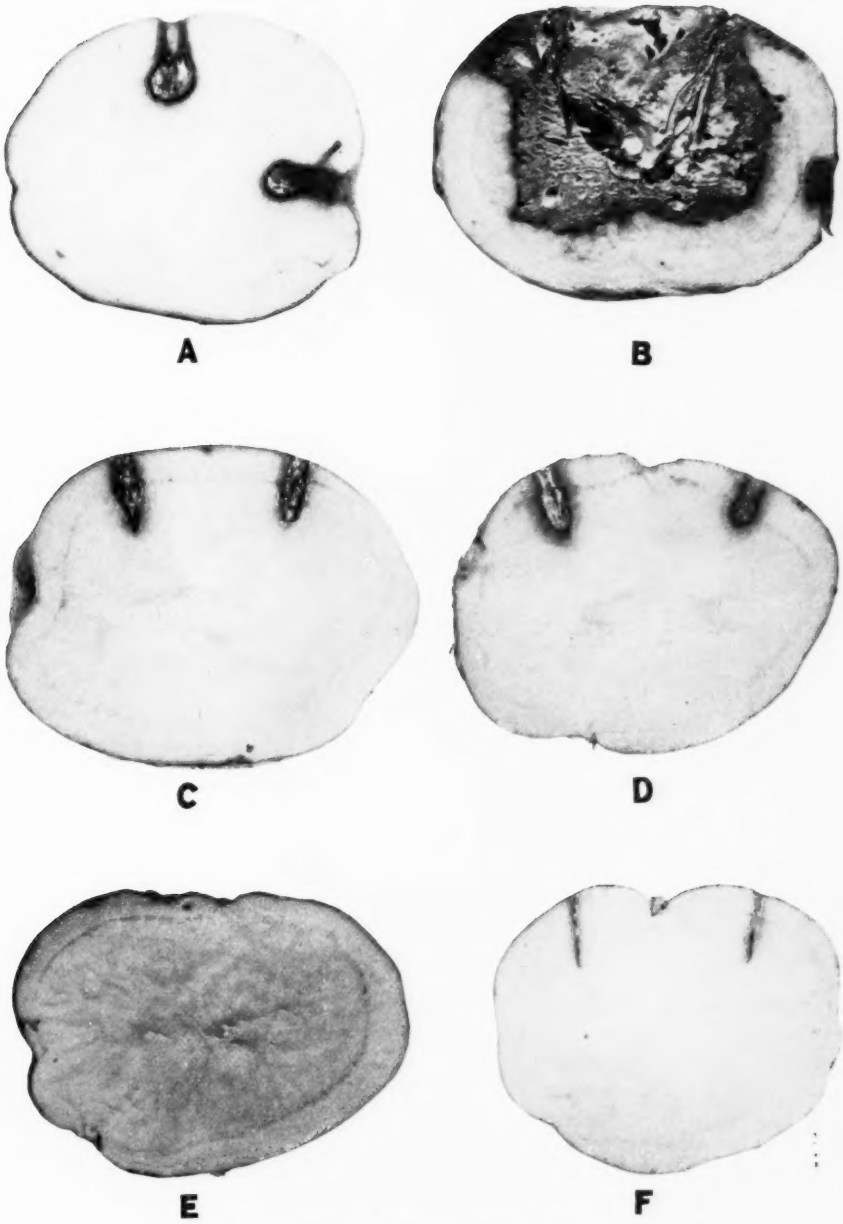
(Slightly reduced)

A. Tuber inoculated with *Clonostachys rosea* in wounds made by a cork borer, three weeks after inoculation.

B. Tuber inoculated with *Fusarium radicicola;* deep scalpel-wounds, three weeks after inoculation.

C and *D*. Tubers inoculated with *Verticillium sp.*, Culture no. 411, deep needle-pricks, three and eight weeks after inoculation respectively.

E and *F*. Checks, shallow wounds and deep needle-pricks respectively.



SHAPOVALOV: POTATO TUBER PARASITES

BRIEFER ARTICLES

WHEAT SCABS AS AFFECTED BY SYSTEMS OF ROTATION[1]

J. R. Holbert, J. F. Trost, and G. N. Hoffer

Just prior to the harvest of 1918 a limited survey was made of the occurrence of wheat scab in the vicinity of Bloomington, Illinois. The survey was confined to 1500 acres in 28 of the most representative wheat fields of this locality. Seed wheat for these fields had been obtained from two sources. Two car-load lots had been obtained from Kansas and the remainder was home-grown seed of the 1917 crop. In each case the variety was Turkey winter wheat. The uniform character of the Kansas seed wheat is indicated by the consistent appearance of a trace of loose smut and of three to four per cent of bunt in all of the fields sown with it. The imported seed was of excellent quality and practically free from scabby kernels. The home-grown seed was slightly inferior to the Kansas seed both in quality and germination, due chiefly to the fact that it contained a greater percentage of scabby kernels.

The history of the rotation and soil treatments of these fields for the past several years is known. The soil is practically all of the brown silt loam type of the Illinois soil survey. The sequence of crops in the rotation is shown in table 1, together with the yield per acre and the percentage of scab.

TABLE 1

Effect of the sequence of crops in 25 fields, on percentage of Turkey wheat plants affected with scab

ROTATION			NUMBER OF FIELDS	SCAB, AVERAGE PER CENT	YIELD, AVERAGE BUSHEL	SOURCE OF SEED
1916	1917	1918				
Corn	Oats	Wheat	5	1.0	36	Kansas
Corn	Oats	Wheat	7	1.4	37	Illinois
Corn	Corn	Wheat	6	10.7	29	Kansas
Alfalfa	Corn	Wheat	1	4.0	33	Kansas
Clover	Corn	Wheat	1	14.0	26	Illinois
	Alfalfa	Wheat	1	4.0	38	Illinois
	Wheat	Wheat	3	2.5	36	Illinois
	Wheat	Wheat	1	Trace	35	Kansas

[1] The work embodied in this report was done in coöperation with the Purdue University Agricultural Experiment Station, Lafayette, Indiana.

Table 1 represents the recent sequence of crops in 25 fields with averages of the percentages of scab occurring in these fields. Where wheat followed two years of corn it showed a very high percentage of scab in practically every case. Wheat following only one year of corn generally showed more scab than when it followed some other crop than corn, though not so much scab as when following two successive years of corn. Wheat grown on parts of fields where the corn had been removed for silage showed a less degree of scab infection and gave a heavier yield than wheat on stalk ground in adjacent parts of the same fields. Scab infection on wheat following wheat was not as severe as on wheat following corn in the same or adjacent fields. Wheat following oats showed the lowest average scab infection. The introduction of an oat crop between corn and wheat always resulted in a marked reduction in the quantity of scab.

TABLE 2

Variations in percentages of wheat scab in different parts of the same field

NUMBER OF FIELD	ROTATION					PORTION OF FIELD	SCAB YIELD		MATURITY RIPE IN	SEED OF SOURCE
	1914	1915	1916	1917	1918		Per cent	Bushel		
									days	
1		Wheat	Clover	Corn	Wheat	East	14	28	3–4	Illinois
		Wheat	Clover	Wheat	Wheat	West	3	35	Ripe	Illinois
2	Clover	Corn	Corn	Corn	Wheat	West	5	20	3–5	Kansas
	Clover	Corn	Oats	Corn	Wheat	East	1	25	1–2	Kansas
3		Clover	Corn	Corn	Wheat	West	20	25	6	Kansas
		Oats	Wheat	Corn	Wheat	East	2	33	Ripe	Kansas

In table 2 is shown a study of scab infection in three wheat fields. Different portions of each of these fields had borne different crops in 1917. The variations in scab infection of the wheat in the two different parts of each field can be attributed only to the influence of different crops during the previous years. All fields were sown with Turkey wheat. The source of the seed and the fertilization of the soil were the same on both portions of each field.

In 1917 the eastern part of field no. 1 was in corn, while the western part was in wheat. The wheat grown in 1917 showed 40 per cent of scab infection. In 1918, wheat on the portion of the field which grew wheat in 1917 showed only 3 per cent of scab infection, while the wheat sown on corn ground showed 14 per cent of infection. The yields were 35 and 28 bushels respectively, and the wheat following corn was three to four days later in maturing.

Field no. 2, which was all in wheat in 1918, was all in corn in 1917. One-half, however, was in corn in 1916, while the other half was in oats. In fact, the west half of this field had been in corn for three years before

the wheat was grown in 1918. On this portion of the field the wheat in 1918 showed 5 per cent of scab and a 20 bushel yield. On the eastern portion which bore oats in 1916 only 1 per cent of scab developed, and the yield was 25 bushels per acre.

In field no. 3, the wheat on the western portion followed two years of corn, while the wheat on the eastern portion followed only one year of corn and this had been removed for silage. The wheat following two years of corn contained 20 per cent of scab and yielded only 25 bushels per acre. Wheat following only one year of corn showed but 2 per cent of scab, yielded 33 bushels per acre, and matured six days earlier than the poorer half.

In all these fields, as also in the majority of the other fields studied, wheat following corn ripened a few days later and much less uniformly than wheat following wheat.

Throughout the extent of the survey, the scab infection was found to center in fairly well defined spots in those fields in which observations were made. One spot might show as high as 10 to 15 per cent of scab, while another, a rod distant, would show as low as 2 to 3 per cent. The relation of the topography to the percentage of wheat scab is shown in table 3.

TABLE 3

Relation of topography to occurrence of wheat scab

ROTATION					PERCENTAGE OF SCAB IN DIFFERENT PORTIONS OF FIELD		
1914	1915	1916	1917	1918	Hill	Base of slope	Bottom-land
	Alfalfa	Corn	Corn	Wheat	8	30	
	Alfalfa	Corn	Corn	Wheat	Trace	15	1
Alfalfa	Alfalfa	Alfalfa	Alfalfa	Wheat	Trace	4–5	
Clover	Corn	Corn	Oats	Wheat	Trace	10	2

The highest percentages of scab seemed to occur at the base of elevations where trash would collect when washed down the slope. While the percentage of scab was invariably higher in lodged wheat, the quantity was not always highest on the lowest, and apparently most fertile, sections of the field. On the other hand, the most elevated portions, generally with thinner stand, gave the lowest scab counts.

This survey indicates an intimate relationship between the occurrence of the scab organism and systems of cropping. The uniformity of all conditions except time of sowing and of soil fertility through the fields covered by this survey, indicates the possible partial control of scab through the practice of proper crop rotation.

BUREAU OF PLANT INDUSTRY
WASHINGTON, D. C.

PHYTOPATHOLOGICAL NOTES

Personals. Mr. J. W. Blachly, formerly a field agent of the Bureau of Entomology, Department of Agriculture, has been transferred to the Bureau of Plant Industry as extension plant pathologist, with headquarters in the department of botany, office of plant pathology, Kansas State Agricultural College, Manhattan, Kansas. He will be engaged in the introduction of practical methods of control for diseases of truck crops, in cooperation with the extension division of the College.

Mr. J. P. Benson, a graduate student and instructor in botany at Cornell University, has accepted the position of assistant pathologist in the office of Cotton, Truck, and Forage Crop Disease Investigations, Bureau of Plant Industry, and will take up work on the storage rots of vegetables.

Mr. J. M. LeCato, formerly extension pathologist of the Bureau of Plant Industry in Virginia, has become associate plant pathologist of the Delaware Agricultural College. He will retain a connection with the Bureau of Plant Industry and will devote a part of his time to extension work on the control of truck crop diseases in Delaware.

Dr. G. W. Keitt, formerly assistant plant pathologist at the University of Wisconsin, but more recently serving with the American Expeditionary Force in France, has been promoted to the rank of captain and placed in charge of gas defense work for about 30,000 men.

Mr. James Birch Rorer, formerly mycologist for the Board of Agriculture, Port-of-Spain, Trinidad, B.W.I., announces a change to the position of mycologist, Associacion de Agricultores del Ecuador, Guayaquil, Ecuador, South America.

Dr. Eugene Washburn Roark died of pneumonia following influenza, at Minneapolis, October 13, 1918. Dr. Roark was a member of the instructional staff of the University of Wisconsin in the department of plant pathology. Upon the completion of his research work leading to the doctor's degree last spring he applied for admission to the naval aviation service and was detailed to the ground school at Minneapolis, September 3, for training.

Dr. Mortier F. Barrus, Pathological Adviser in the Office of Cotton, Truck and Forage Crop Disease Investigations, Bureau of Plant Industry, U. S. Department of Agriculture, has resigned to accept a commission as First Lieutenant in the Quartermaster's Department of the Army.

ABSTRACTS OF PAPERS PRESENTED AT THE TENTH ANNUAL MEETING OF THE AMERICAN PHYTOPATHOLOGICAL SOCIETY, BALTIMORE, DECEMBER 26 TO 28, 1918

Soil disinfection by hot water to control the root-knot nematode and parasitic soil fungi. L. P. Byars and W. W. Gilbert.

During the past year experiments have been carried out to determine the possibility of using hot water as a means of disinfecting small quantities of soil infested with the root-knot nematode, *Heterodera radicicola* (Greef) Mueller, and the "damping off" organisms *Rhizoctonia sp.* and *Pythium debaryanum*. The work was carried out with soil in four and eight inch pots and in shallow benches. It is planned to continue these investigations and expand them to include work on soil in deep beds.

The results already secured are particularly adapted for use when the disinfection of small quantities of soil for growing seedlings is involved, and steam is not readily available, as for example, in the work of the boys' and girls' tomato clubs in the South.

These investigations have shown (1) that immersion of four-inch pots of infested soil in boiling water for five minutes killed all the organisms concerned; (2) that the application of three liters of boiling water to eight-inch pots of similarly infested soil gave identical results; and (3) that the application of boiling water at the rate of seven gallons per cubic foot of infested soil practically eliminated the nematode and fungi from shallow benches.

As a further result of these hot water treatments there was at the same time a marked increase in the percentage of germination and in the size and vigor of the plants grown in the treated soil.

Fusarium root-rot of tobacco. James Johnson.

The deterioration of tobacco soils in the Connecticut Valley and in Maryland has been the subject of considerable study during the past three years. The reduced yields on many fields is not clearly attributable either to loss of fertility or to Thielavia root-rot. The roots of tobacco grown in such soils are usually discolored, decayed in local areas and reduced in area. The plants show no special symptoms of the trouble above ground, excepting that they grow slowly or not at all. Sterilization of the soil either with heat or formalin usually remedies the condition, excepting where the soil becomes toxic on heating or becomes accidentally reinfested. Species of Fusarium have been repeatedly and consistently isolated from diseased roots. Artificial inoculation with pure cultures, although frequently obtained by various methods does not give as consistent results. Environmental conditions seemingly play an important rôle here. The conclusion that Fusarium species are parasitic upon the roots of tobacco is warranted, however. As yet no single species can be said with certainty to be the only one concerned. Furthermore, certain of the strains obtained are apparently not limited to tobacco as a host. Certain legumes, especially cowpeas, as well as tomatoes are attacked.

Oomycetes parasitic on pine seedlings. CARL HARTLEY and GLENN G. HAHN.

Pythium debaryanum has been long known as a cause of damping-off of angiosperms and vascular cryptogams. It is now shown by repeated inoculations, reisolations, and reinoculations to be parasitic on pine seedlings. Single spore cultures, especially difficult to obtain with this fungus, have not been employed in the inoculation work but the cultures used have given reasonably conclusive evidence of purity. Heavy inoculation on autoclaved soils with strains of average virulence invariably yields positive results. Lighter inoculation and especially inoculation on unsteamed soil have less decided effect. Not all strains are virulent, but stains isolated from, and known to be parasitic on dicotyledons are as virulent on pines as strains originally taken from pines.

Rhcosporangium aphanidermatus, known as a parasite on radishes and sugar beet seedlings, has never been found occurring naturally in pines. A single strain in repeated inoculation on *Pinus banksiana* has given positive results and reisolation and reinoculation have been successful. An unidentified species of Phytophthora obtained from *Pinus resinosa* has given evidence of a certain degree of virulence on pine seedlings in inoculations, and another oomycete, probably *Pythium artotrogus,* from *Pinus banksiana* has proven of very weak or doubtful parasitism on pines. *P. debaryanum* is the only oomycete sufficiently virulent and sufficiently common to be considered of economic importance in pine seedlings.

Relative importance of Pythium and Rhizoctonia in coniferous seed beds. ROY G. PIERCE and CARL HARTLEY.

Both *Pythium debaryanum* and the Rhizoctonia stage of *Corticium vagum* are common in damped-off seedlings of pine, and, judging from limited observations, in spruce as well. *Tsuga mertensiana* and *Pseudotsuga taxifolia* are additional hosts for Pythium. These fungi appear to be the two most important parasites on pine seedlings. In examination of several hundred groups of damped-off seedlings Pythium has been found in more such infection foci than Rhizoctonia. Nevertheless Rhizoctonia is probably as important as Pythium, for single Rhizoctonia infections sometimes spread over considerable areas involving large numbers of seedlings. Rhizoctonia furthermore seems to occur more frequently than Pythium in beds consisting of pure sand. In beds given different disinfectant treatments Rhizoctonia was found in a smaller proportion of the foci than in untreated beds, indicating that it is more easily controlled by disinfectant treatments than Pythium.

Both fungi are often found in seedlings from what appears to be the same infection focus. Both have even been obtained from a single seedling. With both fungi some of the strains taken from damped-off pines have proved in inoculation experiments to have little or no capacity for attacking pines. It is evident that finding one of these fungi in a damped-off seedling is not proof of causal relation. There is little difference between the weaker strains of Rhizoctonia and the weaker Pythiums. There have been found, however, a few very virulent Rhizoctonia strains, apparently more destructive to pines than the strongest of the fifty Pythium strains worked with.

Hot water seed treatment for black leg of cabbage. J. B. S. NORTON.

Treatment of cabbage seed with formaldehyde and corrosive sublimate did not prevent the development of fungi that hindered the growth of seedlings in sterile agar tubes. Treatment of seed with hot water showed that cabbage seed could be treated five minutes at 60°C., ten minutes at 56°C., fifteen minutes at 56°C. and twenty minutes at 54°C. without injury. Preliminary tests with the Phoma spores

in hot water indicate that they are killed at somewhat lower temperatures than the cabbage seed. Late cabbage plots from seed treated with water at 5°C. for ten minutes were almost free from Phoma and only a few plants failed to head while the untreated plot was very uneven, especially when young. Many times the number of plants failed to head as compared with the treated plot, and most of the poorer plants were attacked by Phoma.

Macrosporium solani on tomato fruit. JOSEPH ROSENBAUM.

Complaints received from growers and commission men showed the necessity of determining definitely whether or not the early blight or nail-head spot (*Macrosporium solani* E & M) on tomato fruit originates in transit. Experimental data on this point are lacking but statements are found in literature that "the disease had developed during transit."

Recent work with Florida grown winter tomatoes has shown conclusively that this disease does not originate in transit on mature fruit shipped either ripe or green, maturity of the fruit in this case being measured by size. Fruit approximately more than six inches in circumference is not susceptible to the disease even under the most favorable conditions for infection.

The above conclusion was reached in the following manner: (1) by making numerous counts in the field to determine age and size of fruit when infection can occur in the field, (2) sending experimental shipments of mature and immature fruit from badly infected field at intervals throughout the season, (3) artificial inoculation experiments gave positive infection on immature uninjured fruit but failed to infect mature uninjured fruit.

The nematode disease of wheat caused by Tylenchus tritici (Steinbuch) Bastian, and its control. L. P. BYARS.

During the past year the eelworm disease of wheat caused by *Tylenchus tritici* (Steinbuch) Bastian and long known in Europe has been found causing a great deal of damage in certain parts of the United States, particularly in Virginia.

Wheat spikelets affected by the disease contain in place of the normal kernels dark, hard galls filled with larvae of the nematode. These larvae escape from the galls into the soil, reach the young seedlings, become located between the leaf sheaths near the bud and are passively elevated to the spike. There they enter the young flowers and produce the galls within which they develop to maturity and lay eggs. The latter give rise to larvae and in this way their life cycle is completed.

The disease may be controlled by the use of clean seed, crop rotation and sanitation. If uninfected seed cannot be brought in from localities where the trouble does not occur the sound grain may be separated from the nematode galls by the salt-brine method devised by A. G. Johnson of Wisconsin for removing ergot from rye.

The Physoderma disease of corn. W. H. TISDALE.

The Physoderma disease of corn (*Zea mays*) was discovered in India by Shaw in 1910 and in the state of Illinois by Barrett in 1911. Since that time various individual reports and an extensive survey in coöperation with the Office of Plant Disease Survey have revealed its presence throughout the United States as far westward as central Texas and northward to southern Minnesota and New Jersey. The disease is known to cause considerable damage in the South Atlantic and Gulf Coast states. The quantity of damage varies with weather conditions, moist and warm weather favoring its development. For this reason it is thought probable that the disease

has reached its northern and western limits, especially so far as its ability to do any appreciable damage is concerned.

The disease occurs on all varieties of corn and has been found on Teosinte. On the blades of these plants it has the appearance of a true rust when viewed from a distance, but on close observation it can be distinguished readily from the true rust. The reddish-brown spots, which are seldom more than 1 mm. in diameter, often coalesce to give the entire blade or a part of it a rusty appearance. On the culm, mid-rib and sheath the lesions are usually larger, often 5 mm. in diameter and are darker brown in color. The spots are definitely limited by the veins. The culms are in cases completely girdled and the plants often die before maturity. After the plants are dead the pustules may rupture and liberate a brown dust of sporangia. This is especially noticeable where the plants break over.

The resting sporangia (resting spores) of the causal organism, *Physoderma zeae-maydis* Shaw, live over winter on the diseased plants and in the soil and are carried in spring and summer by wind and other agencies to the young corn plants where they germinate in the free water held by the bud and sheath of the plant, producing numerous uniciliate zoospores which are motile for from one to two hours after which time they come to rest, send out delicate thread-like hyphae which penetrate directly the host epidermis and cause the disease. Resting sporangia germinate at temperatures ranging from 23° to 30°C., the optimum temperature being about 28°. After the hyphae have penetrated the host epidermis a number of adjacent cells are invaded by the mycelium which forms an intracellular network of fine fibers and enlarged cells. These enlarged cells develop directly into resting sporangia or send out short hyphae which produce terminal sporangia. The fine mycelial fibers penetrate the cell walls directly. The invaded cells often become completely filled with brown resting sporangia which give the spots a brown color. These sporangia germinate readily as soon as they are mature, but after becoming dry they germinate less readily or scarcely at all until after they have passed the winter. Germination and zoospore formation take place in two days when the sporangia are placed in water at the proper temperature.

The disease is less abundant where farm sanitation and a good system of crop rotation are practised.

Resistance in the American chestnut to the Endothia canker. ARTHUR HARMOUNT GRAVES

Native chestnut trees giving unmistakable evidence of resistance to the bark disease caused by *Endothia parasitica* (Murr.) And. have been discovered in the neighborhood of New York City. Resistance is proved by the following facts:

1. The average growth in 289 inoculations is one-fifth to one-fourth as fast as in ordinary chestnut.

2. The trees occur in a neighborhood long subject to the disease, and among them are individuals long since dead.

3. The trees themselves have had the disease for a long period, as shown by bare, weathered tops, healed cankers, swollen branch bases, etc.

That disease resistance is an inherent character is inferred from the following facts:

1. Association of the trees together in well defined areas.

2. Manifestation by members of the same coppice group, and by branches, trunk and basal shoots of the same individual, of similar degrees of resistance.

Associated with cases of marked resistance is an unusual development of callus tissue in which a peculiar milky-white substance, evidently strong in tannin or tannin compounds, appears.

Many of the trees bloomed well and this fall bore good fruit. The nuts have been planted in order to determine with certainty whether or not the resistant character is a heritable character.

These facts and inferences are of particular significance inasmuch as they suggest the practicability of developing a resistant strain of American chestnut for reforestation purposes.

Notes on some Uredinales attacking pines. GEORGE G. HEDGCOCK and N. REX HUNT.

Caeoma strobilina Arthur causes a serious disease of pine cones in Florida, rendering them abortive. The fungus is a true Caeoma, but often possesses pseudoperidial flaps which protrude from between the hypertrophied cone scales. The first year cones are infected apparently in late winter, and the mature aecia appear in early spring the same year. Inoculations in March, 1918, with the aeciospores of this fungus from cones of *Pinus heterophylla* Muench. and *P. palustris* Mill. at Washington, D. C., infected the leaves of several species of oaks, producing uredinia with small sori in about two weeks. After several months immature telial sori have been produced, belonging to Melampsora or a related genus. The uredinia of this fungus closely resemble those of *Uredo quercus* Brond. of Europe.

Caeoma conigenum Pat. causes a similar cone disease of pines in Arizona. The incubation period of this fungus is apparently longer than that of the previous one, and the cones may bear aeciospores more than one season. The fungus is not a Caeoma but a true Peridermium with cerebroid peridia. Inoculations in July 1918 with the aeciospores of this fungus from *Pinus chihuahuana* Engelm. infected the leaves of oaks producing uredinia with large sori in about two weeks. No mature telia have been formed so far with artificial inoculations. Mature uredinia and telia of a Cronartium associated closely with the aecial form have been found by Hunt in Arizona. Both species of cone rusts apparently winter over in the uredinial form on the leaves of evergreen oaks in nature.

Notes on inoculations with two species of pine leaf rusts are also given, proving new connections between species of Peridermium and Coleosporium.

Notes on the rusts of the piñon pines. GEORGE G. HEDGCOCK, ELLSWORTH BETHEL and N. REX HUNT.

The investigations of the past year have extended considerably the known range of the piñon blister rust *Cronartium occidentale* H. B. & H. It has been found for the first time in northern New Mexico, central and eastern Utah, and southern Wyoming, in the telial form on several species of Grossularia and Ribes, and in northern New Mexico and eastern Utah in the aecial form on *Pinus edulis* Engelm. In Mesa Verde National Park and other regions in southwestern Colorado it is epidemic on this host. Several species of Grossularia and Ribes are now reported for the first time as new hosts.

Coleosporium ribicola (C. & E.) Arthur, which causes a needle rust of *Pinus edulis* in the Rocky Mountain section of the United States, is now reported for the first time from Wisconsin and Minnesota in the uredinial and telial forms on species of Grossulariae, also what is probably the aecial form on *Pinus banksiana* Lamb from Wisconsin.

Results from inoculations with both of these rusts are reported.

Forest pathology and airplane construction. J. S. BOYCE.

For ordinary construction purposes wood is not called upon to meet the exacting requirements that it is for airplane construction. Minor defects in the former instance, may prove disastrous in the latter. Advance rots (the earliest stages of decay), which appear as discolorations in the otherwise sound wood, must be excluded from major parts of airplanes by rigid inspection. It is difficult to separate these discolorations from certain harmless discolorations caused by chromogenic fungi or other agents. Discolorations caused by advance rots are prevalent in Sitka spruce (*Picea sitchensis*), Douglas fir (*Pseudotsuga taxifolia*), birch (*Betula spp.*) and ash (*Fraxinus spp.*), which are probably the four woods most commonly used in airplane construction.

These woods are also subject to many harmless discolorations and in some cases it is necessary to make a microscopical examination to settle whether a fungus is present or not and if present, the effect on the structure of the wood.

Furthermore, certain minor wounds, particularly lightning rings, in coniferous trees, undoubtedly weaken the wood, and parts containing such defects cannot be used.

The actual detection of the above defects depends upon careful instruction of inspectors on duty at the airplane factories by means of actual examples.

There is need for more exact studies on decays, discolorations and minor defects in those woods used for airplanes and through dissemination of such information to inspectors and wood workers in this industry.

Investigations of white pine blister rust, 1918. PERLEY SPAULDING.

These investigations were carried on in 1918 at four field stations; Block Island, Rhode Island; Kittery Point, Maine; North Conway, New Hampshire; and Lewis, New York. At the two latter places the work was carried on under the direction of Doctors H. H. York and L. H. Pennington. It has been definitely established that the aeciospores are distributed for miles rather than hundreds of yards and it appears that the wide dissemination of the disease takes place by this means. The uredospores, this season, were not widely distributed. The sporidia from the telia apparently produced infection for relatively short distances only. The aeciospores germinate strongly and retain viability longest; the uredospores germinate rather weakly and retain viability a somewhat shorter time than the aeciospores; the telia themselves germinate strongly and retain viability a long time; the sporidia are short-lived. Overwintering of the fungus upon dead Ribes leaves has been proved. Seven generations of uredospores were produced in New York. White pines on Block Island bore blisters this spring after an incubation period of about eighteen months.

Fungi which decay weaveshed roofs. R. J. BLAIR.

When the weaveroom of a cotton mill is immediately beneath the roof, the moisture from the air gets into the roof planks and causes them to rot in a short time.

The writer has recently examined 24 of these roofs which cover an area of more than 45 acres. Of the lot, in only 2 (which make less than 1 per cent of the total area) was it found that trouble was not beginning to show in less than six or eight years. Nearly all of these roofs are in New England.

One of the Massachusetts roofs has furnished exceptional opportunities for a study of the problem. This roof is of Southern pine, covers more than 4 acres and has rotted in less than eight years. At least three species of fungi are rotting this

roof, *Lentodium tigrinum, Fomes officinalis and Lenzites trabeum*. The different forms are very nicely distributed in various parts of the roof.

The factors affecting the life of these roofs are: (1) Species of wood, (2) quality of plank, (3) thickness of plank, (4) relative humidity of weaveroom, (5) arrangement of the heating system.

A safe roof can be made of two thicknesses of plank separated by three layers of tarred paper mopped on. The inner plank is of high grade material, while the outer one is of inferior stuff, mostly sapwood which has received preservative treatment. A tar and gravel finish is then put on.

The accial hosts of Puccinia subnitens. ELLSWORTH BETHEL

This is the third report of culture work with this rust. During the summer of 1918, the number of aecial hosts was greatly extended, and now numbers 71 species, and 46 genera in 19 families. The correlated rust, *Uromyces peckianus* Farl., is also discussed, and new aecial hosts recorded.

LITERATURE ON PLANT DISEASES[1]

COMPILED BY EUNICE R. OBERLY, LIBRARIAN, BUREAU OF PLANT INDUSTRY AND FLORENCE P. SMITH, ASSISTANT

October, 1918

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All authors are urged to cooperate in making the list complete by sending their separates and by making corrections and additions, and especially by calling attention to meritorious articles published outside of regular journals. Reprints or correspondence should be addressed to Miss E. R. Oberly, Librarian, Bureau of Plant Industry, U. S. Dept. of Agric., Washington, D. C.

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